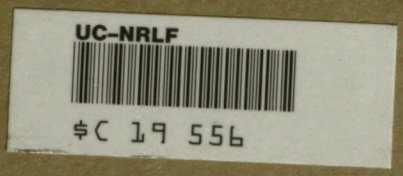

HISTORY

OF

THE BARRAGE

AT

THE HEAD OF THE DELTA OF EGYPT

COMPILED BY

MAJOR R. H. BROWN (LATE R. E.)

INSPECTOR GENERAL OF IRRIGATION IN LOWER EGYPT.

WITH AN INTRODUCTORY NOTE

BY

W. E. GARSTIN ESQre. C. M. G.,

UNDER SECRETARY OF STATE FOR PUBLIC WORKS, EGYPT.

WITH ILLUSTRATIONS

CAIRO 1896.

F. DIEMER, PUBLISHER,

INTERNATIONAL BOOKSTORE.

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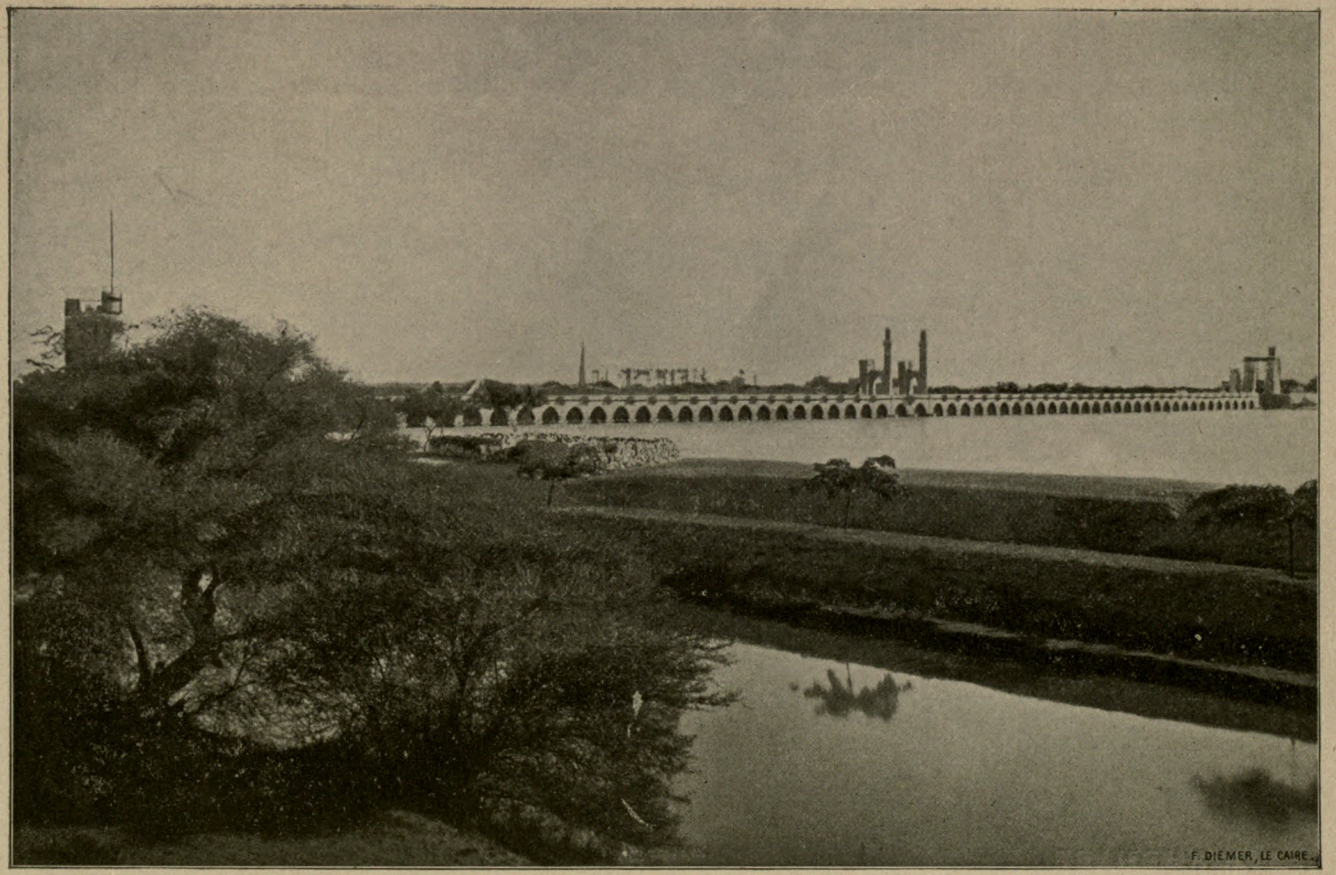

VIEW OF ROSETTA BRANCH BARRAGE FROM DOWN-STREAM.

PHOTOGRAPH BY Mr. ALLAN F. JOSEPH, AT PRESENT IN CHARGE OF THE BARRAGE.

FRONTISPIECE.

View of Rosetta Barrage from down-stream, photographed by Mr. Allan F. Joseph.

The tower with the flag staff, on the left of the picture, marks the East end of this Barrage.

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INTRODUCTORY NOTE

COMPARATIVELY few persons, now-a-days, make any stay in Cairo, without paying a visit to the great Barrage. Picturesquely situated at the apex of the Delta, and separated from one another by an avenue of magnificent acacias, the two regulating dams with their long lines of arches reflected in the water, and their graceful towers, standing out in strong relief against the sky, combine to form a striking and beautiful picture, and one not readily to be forgotten.

When it is considered, moreover, that this structure forms the centre from which the great irrigation system of Lower Egypt is directed and controlled, and that upon its existence depend the fertility of over two millions of acres, and the water supply of several millions of human beings and cattle, it is little wonder that it should form an object of interest to the visitor, rivalled only in importance by the Pyramids, the Sphinx and the Giseh Museum.

Major Brown has thought that a short account of the origin and construction of this work would meet a much felt want, and enable those, possessing no technical knowledge of the subject, to appreciate the long and arduous struggle which its completion has entailed, between the trained energy of man and the forces of the great river, with its immense volume of water, its powerful springs and its shifting sandy bed.

Major Brown possesses special qualifications for the task which he has undertaken. As Inspector General of Irrigation in Lower Egypt, the regulation and supervision of the Barrage are in his hands. As a writer upon scientific questions he has already acquired a reputation, to which several papers, printed by the Royal Engineers Institute, can testify. He is, moreover the author of the work entitled *"The Fayum and Lake Mœris"*, well known to those interested in subjects connected with Egypt.

In the present instance he has, I consider, achieved success. He tells his story so graphically and clearly as to render it easy of comprehension even to persons unacquainted with the rudiments of Hydraulic Engineering. He has an interesting history to relate. His narrative more especially throws a light upon the manner in which vast projects were undertaken and carried out in Egypt during the earlier portion of the present century.

His account of the impatient Viceroy (Mehemet Ali), who directed the demolition of the Ghiseh pyramids in order to furnish stone for the works, and who further commanded that a given quantity of material should, whether required or not, be put daily into the foundations, proves how absolutely the engineers of that period were subject to the caprice of the ruler of the country. Stories of this kind would be amusing, did we not know that such actions played their share in building up the heavy burden of indebtedness, under which Egypt at the present moment labours.

Originating with Napoleon I., the idea of regulating the Nile supply by means of dams was taken up with enthusiasm by the founder of the present dynasty, the great Mehemet Ali. To the talented Frenchman, Linant de Bellefonds, belongs the honour of having first caused this idea to assume a concrete shape. To his compatriot, Mougel Bey, must be awarded the still greater honour of having designed and carried to completion the structure which to this day stands as a monument to his name.

It is true that the work, as constructed by the latter, was faulty in certain of its more important parts, but the faults in question were due rather to the impetuosity and to the arbitrary nature of his master than to any lack of engineering talent on the part of Mougel Bey himself.

Major Brown relates how, for years after its completion, the Barrage remained unused on account of the ominous signs which, from the commencement, it had given of its inability to withstand the strain due to even a moderate head of water.

He describes the numerous commissions which sat upon the work between the years 1861 and 1883, and epitomises the reports made by the many experts who were called in to examine the question and advise the commissioners thereupon.

He explains how the studies of these twenty-two years resulted in the official condemnation of the entire construction in 1883.

He further shows how it was reserved for two Englishmen, Sir Colin Scott-Moncrieff and Mr. Willcocks, to prove in 1884 that the condemned structure could be converted into one that was practically sound. The former boldly accepted the responsibility of attempting what he was universally warned was an impossible task, and the latter vindicated the action of his chief by successfully demonstrating that the Barrage, if repaired, could be used for the purpose for which it had been originally designed.

With these two names must ever be associated those of Lieut. Colonel Western and the late Mr. Reid, who were specially charged with the work of restoration. To them belongs the honour of having repaired the unsound work, and rendered it capable of playing its present important part in the regeneration of Egyptian irrigation. Major Brown indicates clearly the numerous and apparently insuperable difficulties against which these two officers had to contend throughout the progress of the operations, and how it was entirely owing to their high technical skill and to their self-denying labours, that the final results proved to be so satisfactory.

Lastly, as Major Brown informs us, it is to his predecessor Mr. Foster that the credit must be allotted of having perfected the work during the years succeeding the completion of the main repairs. Throughout this period he devoted himself steadily and patiently to the task of staunching the springs which passed underneath the structure, and at the moment of greatest pressure appeared just down-stream of its floor. So successful was he in this, that in the present year (1895) it has not been found necessary to spend any money in connection with the Barrage special repairs.

Those portions of Major Brown's note which describe the foundation of the dam, both as regards the original and the restored work, show very plainly how insecure was the base upon which the construction was founded. With one portion of it built upon shifting sand, and another upon a mass of loose stone laid on the river bed, it is not surprising that, as soon as completed, it should have shown signs of instability. The sudden failure of a portion of the newly laid floor, during the progress of Colonel Western's operations,

indicated, in the most unmistakeable manner, how unreliable was the soil upon which the great mass rested.

Even now, as completed, it would be rash to assert that the Barrage is a thoroughly sound work at every point: it can at best be described as one, which, originally defective, has been repaired as completely as under the circumstances was possible.

Its future must always, therefore, give rise to a certain amount of anxiety. It will always require the most careful handling and the most untiring supervision: these being, however, given, and in the absence of any unforeseen catastrophe, there appears to be no reason for doubting that it should endure for an indefinite period.

One fact is certain: were the Barrage to fail tomorrow, it would, in the increased value of the cotton crop alone, have repaid the sum expended upon its restoration many times over.

Major Brown's figures show, that during the fourteen years preceding the commencement of the repairs, the average annual yield of the cotton crop was two and a half million kantars. In the six years, during which the work was in progress, this figure rose to three million kantars, while in the six years subsequent to the completion of the restoration works, the average annual out-turn was four and three quarter millions of kantars, the figure of five millions having thrice been surpassed.

Briefly then it may be stated, that since the completion of the Barrage repairs the cotton crop in Egypt has been doubled. It cannot, however, be asserted that the above increase is wholly due to the effect of the work in question. Improvements in seed and in the system of cultivation have undoubtedly played their share in the result. Admitting this fact, it can hardly be denied that the improved and assured summer water-supply due to the Barrage must necessarily have been the principal agent in ensuring the increase. If to the above be added the benefits resulting to the country from the economies realised in the annual canal clearances, in the cost of lifting water, and above all in the suppression of the Corvée, the case in justification of the expenditure incurred in the restoration of the Barrage becomes an overwhelmingly strong

one. The Administrators of the Finances of Egypt will, I am sure, cordially allow how considerable a share in the improvement of the revenues of the country is due to the work in question.'

It is to be hoped that the time is not far distant, when Mougel Bey's grand work will form a single portion of a great system, by which the inhabitants of Southern Egypt, and even those of the Soudan, shall profit to an extent equal to that already experienced by their more fortunate brethren in the North from the construction of the Great Barrage.

W. E. GARSTIN,
UNDER SECRETARY OF STATE FOR PUBLIC WORKS.

CAIRO, December 1895.

NOTE:

Since the above was written, we have decided upon taking further precautions against failure, and upon strengthening those portions of the structure which are known to rest upon an unstable foundation. The system to be employed is that invented by Mr. Kinipple M. I. C. E., and consists in the removed of the bad subsoil and the substitution of sound material forced in under pressure.

The above work will be commenced upon a limited scale during the ensuing winter, and if we are satisfied with the results obtained, will be gradually extended throughout the entire construction.

CAIRO, July 1896. W. E. G.

CONTENTS.

LIST OF PLATES.

PREFACE.

ON becoming Inspector General of Irrigation in Lower Egypt, I felt the want of a collected account of the History of the Barrage, and moreover I was informed by a publisher, that requests were frequently made to him for such a work. I therefore put the following account together for my own information and for the convenience of those who take an intelligent interest in Egypt and its modern works of utility, which bring riches to its people. It will serve as a variety to the guide-books, which deal with Egypt and its Ancient Monuments of Vanity, on which the country's wealth was purposelessly spent.

I have not attempted to make the account sufficiently light for the tourist whose mental digestion is upset by all descriptions of solid food. For him the Barrage will be looked upon as a pleasant spot for a day's picnic, and that is all: "A primrose by the river's brim, a yellow primrose was to him, and it was nothing more."

The History of the Barrage naturally divides itself into two periods, (1) that of Projects, Construction and Confessed Failure, and (2) that of Practical Experiments, Restoration and Acknowledged Success. A short Chapter descriptive of the Barrage and its Object, separates these two periods in the following account.

The works, from which extracts, often literal and lengthy, have been made and illustrations borrowed to form this compilation, are the following: —

"Memoires sur les Principaux Travaux d'utilité publique exécutés en Égypte" par Linant de Bellefonds Bey.

"L'Égypte, son avenir agricole et financier" par Félix Paponot.

"Note on the Barrage" by Sir C. Scott-Moncrieff, K.C.M.G. C.S.I.

"Irrigation in Egypt", Lectures by Sir C. Scott-Moncrieff, Professional Papers of R.E., Vol. XIX.

"Egyptian Irrigation" by W. Willcocks, M.I.C.E.

"Annual Irrigation Reports, Egypt" from 1884 to 1894 inclusive.

Manuscripts in the Khedivial Library, and Public Works Ministry, Cairo, have also been consulated.

The two general views of the Barrages and the view of the road-way, showing the displacement of 1867, were photographed for this paper by Mr. Allan F. Joseph, who is the Inpector at present charged with the care of the Barrage and its regulation. The two other photographs, showing the work of restoration, were taken for the Egyptian Government in 1889 by Mr. J. Heyman, a professional photographer of Cairo.

CHAPTER I.

History of the Barrage previous to 1884.

Conditions necessitating a Barrage.

IT is recorded by Clot Bey that Napoleon Bonaparte when in Egypt in 1798 and 1799 during the French occupation, foresaw the construction of a Barrage at the head of the Delta to control the distribution of water in the two branches of the Nile; and that he gave expression to his anticipations of the future in the following words:—

"Un jour viendra où l'on entreprendra un travail d'établissement de digues barrant les branches de Damiette et de Rosette au ventre de la vache, ce qui, moyennant des batardeaux, permettra de laisser passer successivement toutes les eaux du Nil dans une branche ou dans l'autre et de doubler ainsi l'inondation."

The day that Napoleon is said to have foreseen soon came in the reign of Mehemet Ali, who became Viceroy of Egypt in 1805. He was a man of energetic action and lost no time in introducing a period of activity in irrigation works, making use of the unpaid labour of the Corvée as his instrument for carrying them out.

At the commencement of his reign, Lower, as well as Upper Egypt, was irrigated under the basin system, that is, by inundation, and depended on the height of the flood for its water-supply. Too low a Nile would leave

unfavourably situated lands without inundation, and hence the idea, that had suggested itself to the mind of Napoleon, of a Barrage for obtaining such control over the river that a flood, which was a low one in the united Nile above its bifurcation, could be made a high one in each branch of Lower Egypt alternately, by adopting, as it were, the military principle of concentrating one's forces in succession on the separated parts of an enemy's army and defeating them in detail.

The development of cotton cultivation on a large scale in Lower Egypt during Mehemet Ali's reign necessitated a radical change in the whole canal system. Under the basin system winter crops, such as wheat, barley, beans and clover, were grown on the lands from which the Nile flood had retired after inundating them. But cotton cannot be grown under these conditions, for it requires to be protected from inundation, and also to be planted and irrigated before the Nile begins to rise. Hence it became necessary to embank the branches of the river for the protection of the cotton cultivation from inundation, and to dig deep canals to conduct the low level waters of the summer Nile to the neighbourhood of the crops to be irrigated. The water, being so much within soil, had, during the low Nile season, to be lifted onto the land by pumps, sakyas or shadufs. To make and maintain the Nile banks, so as to be capable of resisting high floods, and to dig and keep clear the canals, so that they should be deep enough to flow at low Nile, was a task that fell heavily on the country, and had to be executed by unpaid labour. Linant Bey calculated that the quantity of work necessary for the effective clearance of the canals alone, (without taking into account the maintenance of the Nile banks,) would have come to over 13 million cubic metres a year, requiring an army of 27,404 men working for 100 days to execute it. Such a clumsy system was unable to produce the results desired, though the taskmasters did not fail through tender-heartedness to make the lives of the labourers bitter with hard bondage in those days when the "Koorbash" was still a recognised and favourite instrument of government.

So it became necessary to devise some more scientific method for obtaining and distributing water. The configuration of the Delta naturally

suggested the construction, across the heads of the two branches of the Nile, of Barrages or Regulators, which would raise the low level of the summer Nile by such an amount that water would flow into the canals, taking off from above the regulators, at so high a level that it would not be necessary to clear the beds to a greater depth below country surface than was reasonable and practicable.

But, before such a project took shape, Mehemet Ali had, in 1833, boldly commenced operations for increasing the Damietta supply at the expense of the Rosetta. The water levels of the Damietta Branch being always higher than those of the Rosetta, the irrigation of the part of the Delta, which lies between the two branches, as well as the part on the East of the Damietta Branch, was carried on almost entirely from canals taking off the last named branch. Therefore, to obtain more water during summer in those canals which served as perennial canals for the Central and Eastern Delta, Mehemet Ali, with but little consideration for Beherah Province and regardless of the water supply of Alexandria, proposed to dam the Rosetta Branch by a bank of loose stone, and divert all the water into the Damietta Branch. The idea was a bold one, but this is the only complimentary epithet that can be applied to it. If the proposal had been carried out, it would probably not have succeeded, which would have been a matter for congratulation, as success would have had more unsatisfactory results than failure.

Proposal to construct a Barrage.

The work of damming the Rosetta Branch at Koratayn had actually been begun, when Linant Bey (afterwards Linant Pasha), then in charge of the Irrigation of Upper Egypt, arrived from the South. He at once pointed out the probable consequences of such a violent interference with natural arrangements, and proposed the construction, across the head of each branch, of a Regulating Barrage designed to give command over the distribution of the water between the two branches in summer, and to leave a free passage for

the river during a flood. Whereupon, with nothing but the bare proposal before him, Mehemet Ali, with characteristic impetuosity, forthwith ordered M. Linant to proceed with the collection of the materials necessary to carry out his proposals, after going through the form of submitting a note to the "Grand Conseil". M. Linant was then pressed by the members of the Council to state what materials were necessary, and, in order to satisfy their impatience, he gave a figure of the quantity of ashlar, rubble stone and lime required, asking that a Commission might be appointed to study the whole subject.

At this stage Mehemet Ali, with his mind excited by the Barrage project and more impatient than his Council, proposed to M. Linant to dismantle the Gizeh Pyramids in order to utilise the stone from them in the construction of the Barrages. M. Linant, knowing how to deal with his master, as an Irishman knows how to persuade his pig to move in the right direction, did not oppose the idea as an unparalelled act of vandalism, but proceeded to prepare a project for the demolition. Surrounded by the halo of a Commission, composed of the Ministers of Foreign Affairs, Public Works and Public Instruction, he went to the Pyramids, and prepared his project for their demolition, according to his own account conscientiously. Whether conscientiously arrived at or not, or with a bias in favour of the continued existence of the Pyramids, the final results of the calculations showed that it would be more economical to obtain stone direct from the quarries than from the Pyramids, which consideration turned the Viceroy from his purpose. And so the Pyramids remain to this day to grow yet older.

The Commission, which M. Linant asked might be called to study the project of the Barrage, was meantime formed and included a charming variety of assorted talent. The members were an architect, the Chief Engineer of the Delta, the Director of the School of Engineering and a retired boatman in the confidence of the Viceroy, all of the foregoing being Egyptians. To these were added two English engineers, a foreign engineer who had studied in England, two French Commandants of Artillery and a French mining engineer.

This commission divided into two camps in favour of different projects. It is a wonder it did not divide into more. The one camp advocated the

construction of a solid dam or weir with fixed height of crest, on each branch of the Nile, at Dégoné on the Damietta Branch and at Beni Salama on the Rosetta. It was proposed in this scheme that the flood should pass *over* the dam, and also through a large opening at each end of it, which would be opened in the flood season and be kept closed during summer, on the principle of the ancients with their under-sluices, as constructed in India. The English element in the Commission gave its support to this project, not improbably influenced in its favour by what they had learnt had been done with success in India, where however the conditions were different. It was urged as an objection to the adoption of such a form of dam in Egypt that it would be difficult to raise the *summer* level of the River to the extent desirable by such a permanent obstruction without raising the *flood* level to an undesirable extent up-stream, and, as a result (in the case of the Delta Barrage) inundating Cairo and much else. Further it was argued that the power of distributing water in summer, as might be wished, between the two branches would not be obtained by such an arrangement.

In connection with this proposal it is interesting to note that, when in later years the question of restoring the unsound Barrage was under consideration, Mr. Willcocks made a proposal to remove *all* the piers and to raise the floor permanently 2.50 metres: on the top of this floor he proposed to add moveable drop gates 1.50 metres high. He maintained that a solid wall 2.50 metres high would not obstruct more of a *high* flood than the present piers do. But though this would have been creating a solid immovable dam or weir, such a weir would not have had a *fixed* crest, as the gates of 1.50 metres height would have been made use of for raising the summer level to the extent desirable, while at the same time the fixed obstruction would not have raised the flood level to an extent greater than the existing Barrage does.

Linant's Project.

The other project, favoured by M. Linant and the rest of the Commission was to construct open Barrages across the two branches as near as possible to the head of the Delta, then at Derrawé; the Rosetta Branch Barrage to be situated at Kafr-Mansour and the Damietta Branch Barrage below Derrawé, at both which sites the bends of the river favoured such a disposition of the works. These two Barrages were, according to this project, to be regulators capable of raising during summer the water level up-stream of them to the height required to supply the three main canals which were destined to irrigate nearly all Lower Egypt. During the time of flood the regulating apparatus was to be removed, so that the river might be given a free passage through the Barrage, and not be headed up.

Execution and Abandonment of Linant's Project.

The latter project, which was undoubtedly the more suitable one, received the Viceroy's approval, and the excavation for the work was begun forthwith towards the end of 1833 by mans of Corvée labour, the men being sent onto the work by the orders of the Viceroy in such numbers as to cause considerable embarrassment to those in charge of the work. But in spite of the confusion that overcrowding produced (and only those who have worked with Egyptian labourers can appreciate what that means), a start was made, and work went on fairly well, until in 1835 the plague, that Kinglake describes in "Eothen", visited the works and made itself master there for four months, during which period the works were suspended. Still the preparation of the project progressed, so that, in July 1835, M. Linant was able to present to the Viceroy the designs and estimates of the Barrages complete, and to get them accepted. By this time the plague had left. But the work itself seems to have been stricken by the pest, for it languished as one doomed to die.

The numbers of the labourers dwindled, materials ceased to arrive, and M. Linant himself, now no longer occupied in attending to the construction of the Barrages, was called in 1837 to the Ministry to direct the Public Works Department.

The Viceregal interest would have been capable of reviving the spent energy, but His Highness Mehemet Ali had grown tired of the Barrages, and from being impetuous had grown lukewarm. In this state of mind he appointed a Commission of sixteen members to examine the question of the desirability of such constructions. To this Commission his view, that Barrages were not necessary, was enough plainly indicated to guide a subservient Commission to conclusions in agreement with His Highness's views. But the Commission did not take the hint though so plainly given, and declared decidedly in favour of Barrages as proposed by M. Linant, setting forth in its report the advantages that would result from their construction and recommending a continuance of the work. The Viceroy, notwithstanding, after reading this report, replied officially to the Minister, that the Commission was quite right, but still he did not want Barrages. The materials collected were therefore removed from the site of the projected regulators to other works, and the workshops dismantled for the sake of the wood of which they were constructed. And that was the end of M. Linant's Barrage, a child still-born.

Mougel's Project.

A few years later, in 1842, Monsieur Mougel (afterwards Mougel Bey) arrived in Egypt to construct the graving dock in Alexandria. On an occasion presenting itself, he proposed to Mehemet Ali another system of carrying out the construction of the Barrages, with which he combined a scheme of fortifications to please the military mind of the Viceroy. He claimed to have discovered an artificial puzzuolana in Alexandria, which made the construction of a Barrage a more hopeful undertaking. His Highness listened, and, pleased perhaps with the idea of making the Barrage a military centre, directed

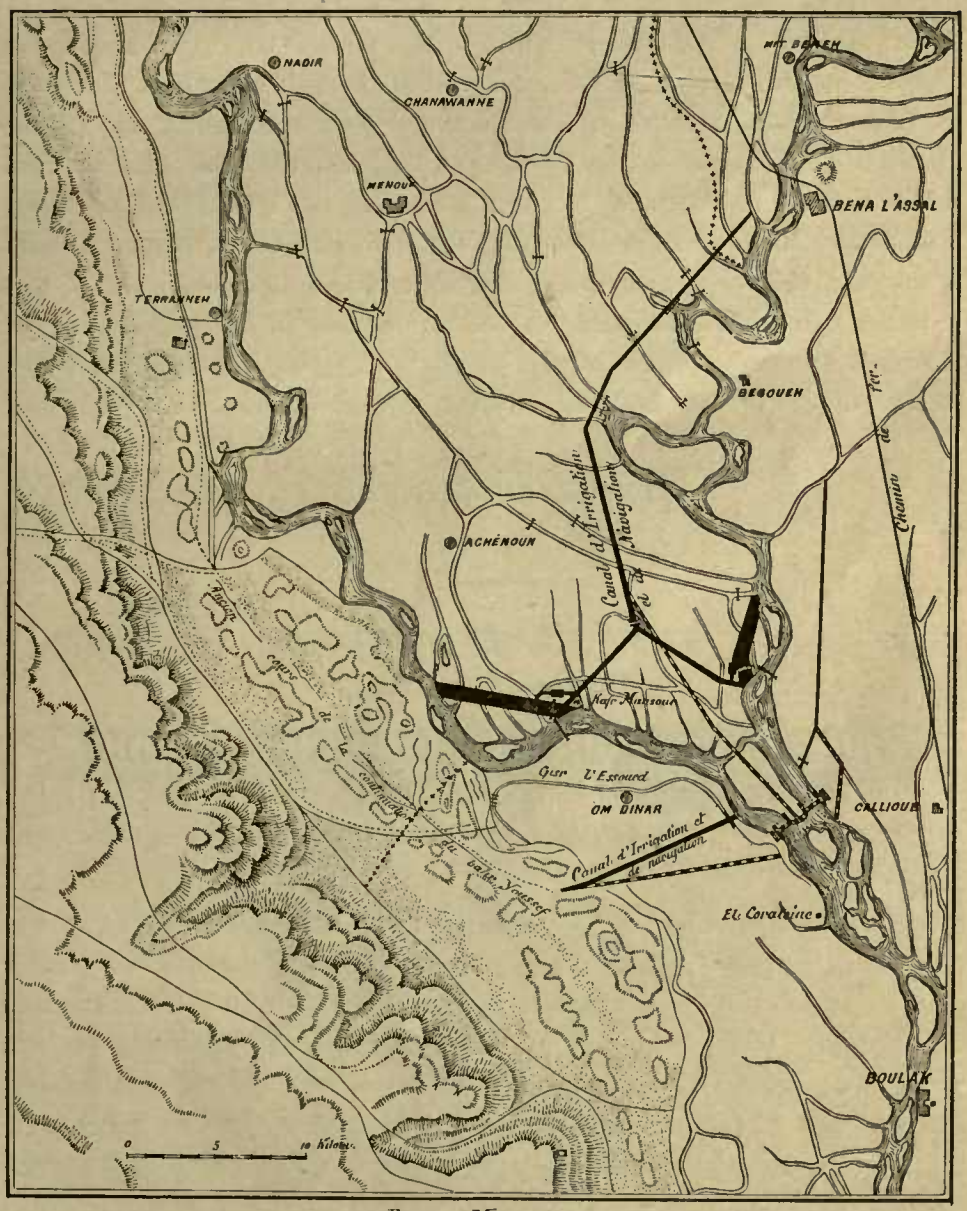
M. Mougel to prepare his project, at the same time calling upon M. Linant to give him all information possible, as well as the benefit of his experience. In compliance with this order M. Linant handed over his complete project to M. Mougel, not, we may be sure, without some feelings of bitterness as he parted with the unused baby clothes of his still-born child for another's child to wear.

In January 1843 M. Mougel laid his project before the Conseil des Ponts et Chaussées. The design of the Barrage, according to this project, gave 39 arches to the Rosetta Barrage and 45 to the Damietta, all of 8 metres width divided by vertical iron uprights into two bays of 4 metres width. It was intended to hold up to 6 metres above Low Water Level. Mougel considered (and subsequent experience has shown him to have been right) that *all* the Low Nile water was required for irrigation and that the work should be designed to provide for its being all utilised. But the Conseil des Ponts et Chaussées thought that this was "almost absolutely impossible" of attainment, as they calculated that the canals could not be made to carry the whole of the summer supply. And not only did they consider it to be impossible, but even undesirable, as navigation and sanitation along the two branches would suffer seriously were the whole summer supply diverted into irrigation canals. Finally the Council gave it as its opinion that the project had not been sufficiently studied.

But that was nothing to Mehemet Ali: sooner than delay, he adopted the project as it stood and gave orders for the construction of the Barrages and the fortifications combined with them, under the direction of M. Mougel. The Barrage which now exists is the result of this order, but the original design was modified.

PLATE I.

EXTRAIT DE LA CARTE DE LINANT DE BELLEFONDS BEY

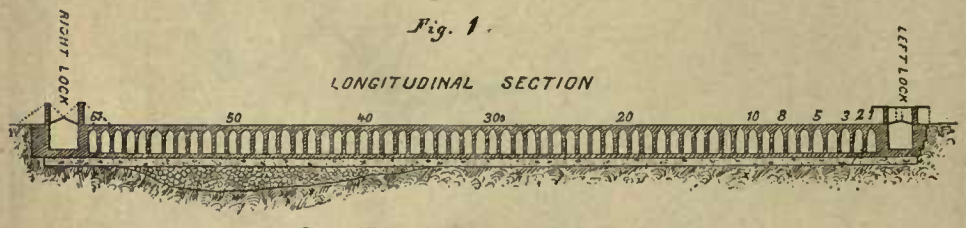


Comparison of Linant's and Mougel's Projects.

It will be convenient before going further with this account to compare the two projects of M. Linant and M. Mougel. The sites chosen for M. Linant's Barrages were on the Rosetta Branch 9 kilometres and on the Damietta 5 kilometres to the North of the present one, (see Plate I), and the sections of the Barrage on either branch of the river would have been 6 kilometres distant the one from the other. In the present Barrage, which is Mougel's, the two sections are so near as to almost form one work, so that it is the custom now to speak of the two together in the singular as "the Barrage". In consequence of this union, the regulation of the Barrages themselves, and of the Canal Heads taking off above them, is easily controlled

ROSETTA BRANCH BARRAGE

Fig. 1.



From Willcocks "Egyptian Irrigation".

by one Director in charge of the whole; and the daily examination of all the Regulators is much facilitated, especially now that a tramway for trollies connects all the parts of the Barrage by which the water distribution is effected. The separation of the Regulators by long distances, as in M. Linant's project, would not have been such a convenient arrangement as the one actually adopted. But M. Linant claims on behalf of his project, that he would have had more reliable constructions, since his works would have been built in good

soil, while M. Mougel's were actually founded upon loose sand. Also, since the works, as designed by M. Linant, would have been built in the dry outside the course of the river (which would not have been diverted through them until they were complete), the foundations could have been given a level bed and the concrete have been laid in the dry: whereas, building as Mougel did, in the river bed itself, the work was founded on an uneven surface, and the concrete was, to a great extent, laid in running water. The varying levels of the bed are shown in Fig. 1, which is a longitudinal section along the Rosetta Barrage. At the West end of this line the sand bed rose 4 metres above the summer low water level, while towards the East end the river bed was 16 metres below the same water level. (See also the diagram, Fig. 2) Hence the West end was founded on loose sand, and the East end on a mass of rubble stone, 12 metres in height and 60 metres broad at the deepest part, which was pitched in to form a platform for the concrete to be laid upon. (See also Plate II.) The concrete layer was consequently formed in running water, and did not therefore set and had to be relaid, probably more than once.

Execution of Mougel's Project.

For the 8 years succeeding the acceptance of M. Mougel's project in 1843, the construction of the Barrage was carried on fitfully with more or less rapidity and success. The Damietta Barrage was begun first and no special difficulties are recorded as having been met with in connection with it. No account exists of the condition of the foundations, but Mougel stated that the work here is excellent, since it was practically built in the dry.

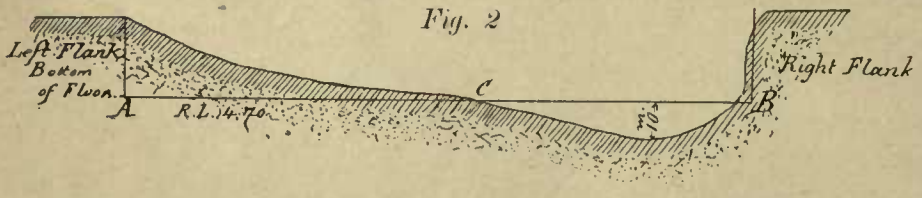
In June 1847 the Rosetta Barrage was begun. Mehemet Ali, impatient for the completion of the work, ordered that 1000 cubic metres of concrete were to be laid daily whether possible or not. It so happened that in this year the river level in April was more than one metre higher than it had been at the same time the year before. Difficulties were also occasioned in

consequence of the earth excavated from the foundations having been thrown too near the edge of the pit, and therefore causing slips, which interfered with the work. M. Mougel attempted to carry out the Viceroy's order in spite of difficulties and technical objections to doing so, knowing that he would have been dismissed, had he acted otherwise. In went the concrete, as fast as it could be got in, to too shallow a depth at the West end, and into running water at the East end over the loose rubble mass. Naturally the lime of the concrete mixture was carried away by the current, and the concrete lost the ingredient which gave it the property of setting. Naturally also springs found their way through the material that remained and upon which the Barrage was to be founded.

The following account* of the manner in which the Barrage was constructed was given to M. Willcocks by Mougel Bey himself and is therefore worth reproducing in full: —

"A level of 8.80 metres above the Mediterranean Sea (or 8.20 metres on the Barrage gauge) was fixed as the mean bed of the river at the bifurcation. The floor was to be 3.50 metres deep, and consequently a reduced level of 4.70 metres was the formation level of the bottom of the floor. Owing to scour along the right bank of the Rosetta Branch, the bed of the river was some 10 metres below this level at the deepest points; while on the left bank there was considerable silt deposit above it.

Fig. 2



If the above Fig. 2 represents a cross section of the Rosetta Branch at the site of the Barrage during construction, and the line AB the bottom

* "Egyptian Irrigation" by Willcocks p. 157.

to the floor, the part from A to C, where the floor is below the bed of the river, was first constructed. The sand was excavated as far as possible in the dry, and then two rows of sheet piling were driven along the up and down-stream faces of the platform. In the cross section Fig. 3, E F and G H are sheet piles; within the sheet piling the sand was dredged out down to a reduced level of 4.70 metres, and concrete skipped into the water to its full thickness of 3 metres, and then allowed to set. Next season the sand was removed from above the concrete K L, and a coffer-dam M N, Fig. 4, was erected on the concrete, enclosing the space to be occupied by about five openings. The coffer-dam was made water-tight and the water was pumped out. The springs through the concrete were then staunched, the stone and brickwork floor O P laid over the concrete, and the piers raised to one metre above water-level.

Fig. 3

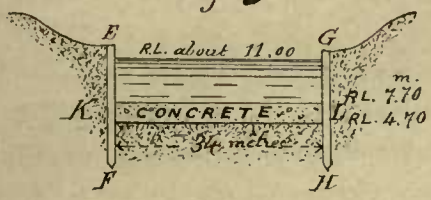
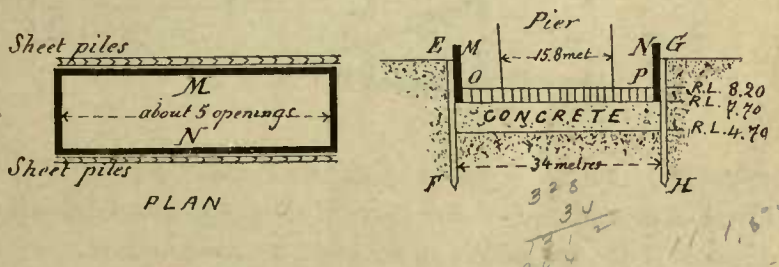


Fig. 4

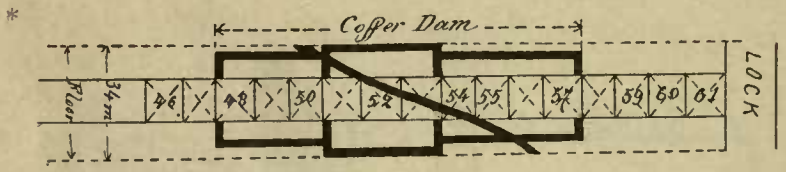


The coffer-dam was then moved forward, and the space to be occupied by five new openings enclosed, and treated in the same way. The sheet piling, E F and G H, was not cut down to floor level, but projected both up and down-stream of the platform to a height of one metre above the floor. There seems to have been no difficulty experienced in this method of working, except under the arches numbered 7, 8, 9 and 10, near the left flank; here the sand was of a particularly fine quality, dark in colour and very light,

with the springs strongly impregnated with decayed organic matter. In spite of the dredger working in still water, the fine sand poured in fast from between the piles, and after being dredged was allowed to accumulate to a height of 8 metres and upwards, just outside the sheet piles. The more it accumulated the more the silt ran in, until the deepening of the trench became an impossibility.

Mougel Bey wanted to postpone the work to the following year, but the Viceroy was urgent: men were crowded into the quicksand, the concrete skipped in, and the mixture of concrete and quicksand had to do duty for the floor. Mougel Bey says that the concrete there could not be more than 1.50 metre thick; Linant Bey says that the springs there were always considerable, cracks appeared in the superstructure before any water was held up on the Barrage, and eventually this part of the Barrage failed and was surrounded by a coffer-dam Fig. 5.

Fig 5



Referring to the cross section of the river Fig. 2 on page 12, it will be seen that the construction of the Barrage along the part C B, where the floor is higher than the bed of the river, could not have been carried out as above. Here a mass of loose stone was pitched into the river from boats, until the upper surface of the tipped stone corresponded with the bottom of the platform on the line A B. Into this barrier of stone, sheet piling (along the up and down-stream edges of the platform) was driven in as far as it

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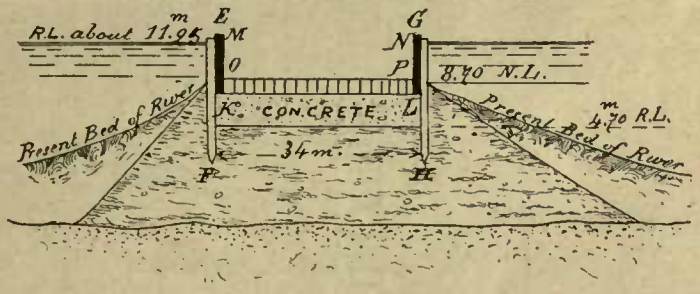
* The numbers of the arches given in Fig. 5 are according to the old method of numbering. According to the new method No. 61 of Fig. 5 should be No. 1 and No. 46 should be No. 16.

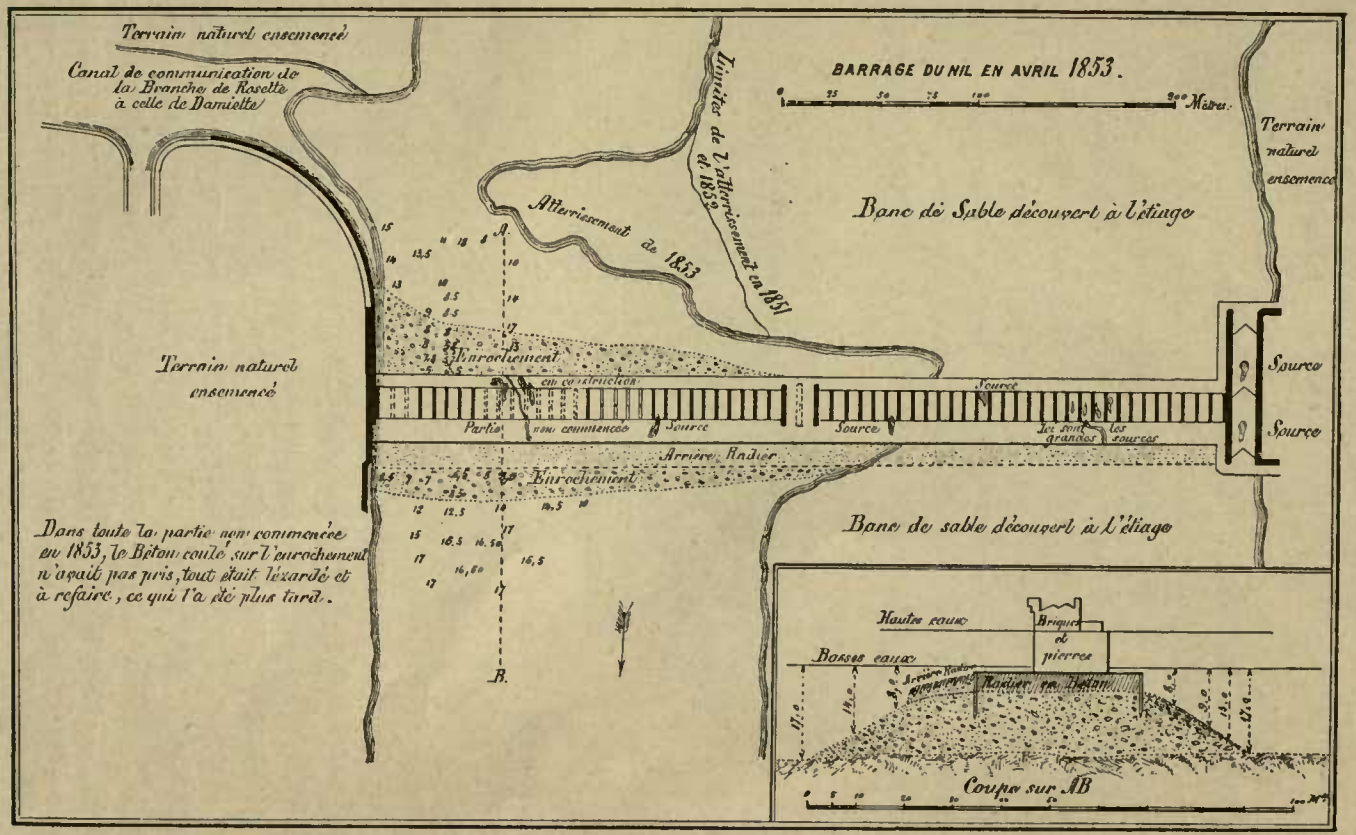
could go. Sail cloth was laid on the up-stream side of the piles and held against the piles by the force of the current. The concrete was skipped into the water between the piles. As much of this concrete was skipped into running water, great part of the lime was washed away, according to Linant Bey. Subsequently when the coffer-dam, Fig. 6, was erected on the concrete for the completion of the floor and superstructure, the springs in places were so excessive that the floor level had to be raised 50 centimetres above the general level. The concrete was composed of broken stone, pure lime and artificial puzzuolana in the ordinary proportions. Much of this concrete has not set, and in places has been found like pudding, though in others it is as hard as rock."

Fig. 6



Meantime, while this work was going on, Mehemet Ali died in 1848 without seeing the completion of the Barrage, which was to be many years before it recovered the injury done to its constitution by his impatience and impetuosity. He was succeeded by Abbas Pasha, who, in March 1852, having no faith in the success of the Barrage as being constructed, was desirous of abandoning the work; but he did not do so for fear of public opinion. At this same time also M. Linant declared himself in favour of pumping establishments in preference to completing the Barrage, and defended his change of opinion on the ground that during the last 10 years pumping machinery had been much improved and rendered economical.

PLATE II.


BARRAGE DU NIL EN AVRIL 1853.
Mètres
Terrain naturel ensemencé
Canal de communication de la Branche de Rosette à celle de Damiette
Limites de l'Atterrissement en 1851 et 1853
Atterrissement de 1853
Banc de Sable découvert à l'étiage
Terrain naturel ensemencé
Enrochement
en construction
Source
Partie non commencée
Arrière Radier
Dans toute la partie non commencée en 1853, le Béton coulé sur l'enrochement n'avait pas pris, tout était lézardé et à refaire, ce qui l'a été plus tard.
Banc de sable découvert à l'étiage
Hautes eaux
Basses eaux
Briques et pierres
Radier en Béton
Coupe sur AB

In April 1853, Abbas Pasha, not being satisfied with the progress made, dismissed M. Mougel, and ordered him to hand over the incomplete Barrage to Mazhar Bey. At the time of transfer a Commission reported on it to the effect that the concrete floor over the rubble heap and elsewhere was in a bad state and that springs found their way through it. M. Linant relates that at the time of transfer the work was far from being finished, as there were scarcely any of the piers constructed to above water-level: he also adds that up to this time 47 million francs had been spent on the work besides the labour of the Corvée and soldiers. The state of the work in 1853 according to M. Linant is shown on Plate II.

In spite of the Report made at the time of transfer, work was continued without remedying the defects in the foundation and making the concrete layer sound: the piers were completed and the whole superstructure of road, pathways, parapets and turrets completed by 1861. The cost, exclusive of the value of the Corvée labour, is said to have been £ 1,880,000. M. Willcocks in his "Egyptian Irrigation" states that the Barrages, fortifications, canal heads &c. are considered as having cost the country £ 4,000,000.

Period of Commission and Reports.

The condition of the Barrage at this period is recorded in the Reports of two more Commissions, one appointed on the 13th November 1861, and the other on the 4th July 1863. At the time of the first Commission no other cracks were remarked except those which existed from the beginning of the construction in the 1st, 2nd and 3rd arches of the West end of the Rosetta Barrage, and these did not appear dangerous. The Commission considered that little remained to be done to complete the Barrage and fill it for the object for which it was designed, but recommended that, before holding up the water at all the floor should be finished and the springs should be stopped by the aid of a diving-boat ("bateau plongeur") in preference to the

employment of dams ("batardeau"); for it was feared that if a head were put on the work, water would pass through the loose rubble heap. The first Commission after making this proposal, adjourned for more information, which it never got.

The second Commission of July 1863 pointed out that the works recommended by the former Commission had not been carried out, that the experiments required had not been made and that the springs had not been stopped. The system of gates was condemned. This Commission came to much the same conclusions as the former, and recommended postponing the digging of the Main canals taking off above the Barrage, until it had been tested.

But in this year the want of water in the Damietta Branch made itself felt during the summer, and, in order to feed the summer canals, the gates of the Rosetta Branch, which had been erected, were closed, and the water-level raised above the Barrage from 1.00 metre to 1.40 metre. The result was that the sand below the floor was forced out by the pressure, and ominous cracks appeared. Later, in 1867, a section of the Rosetta Barrage, consisting of 10 openings (Nos. 5 to 14) towards the West end, separated from the rest of the work and moved perceptibly down-stream. (This is visible now in the existing work, and is clearly shown by the shadow of the parapet wall in Plate III.) These 10 openings were then enclosed within a coffer-dam 5 metres high and 2 metres wide, composed of a wooden framework, filled with stiff clay, overlaid by stone resting on the platform.

M. Linant's last connection with the Barrages (which in principle he claims to have proposed, though the actual project adopted was M. Mongel's and not his) appears to have been the writing of a Report on it in 1871. This is his account of the work as it existed then:

"Le Barrage est comme un corps gangrené: il est recouvert d'un beau surtout, mais la maladie le travaille intérieurement; toutes ces sources sont autant de fistules, qui, quand on veut les fermer, circulent intérieurement et se reproduisent plus loin. Il faut de grandes opérations, de grands remèdes et non des palliatifs, qui ne feraient qu'empirer le mal."

In this same Report M. Linant admitted the possibility of putting the

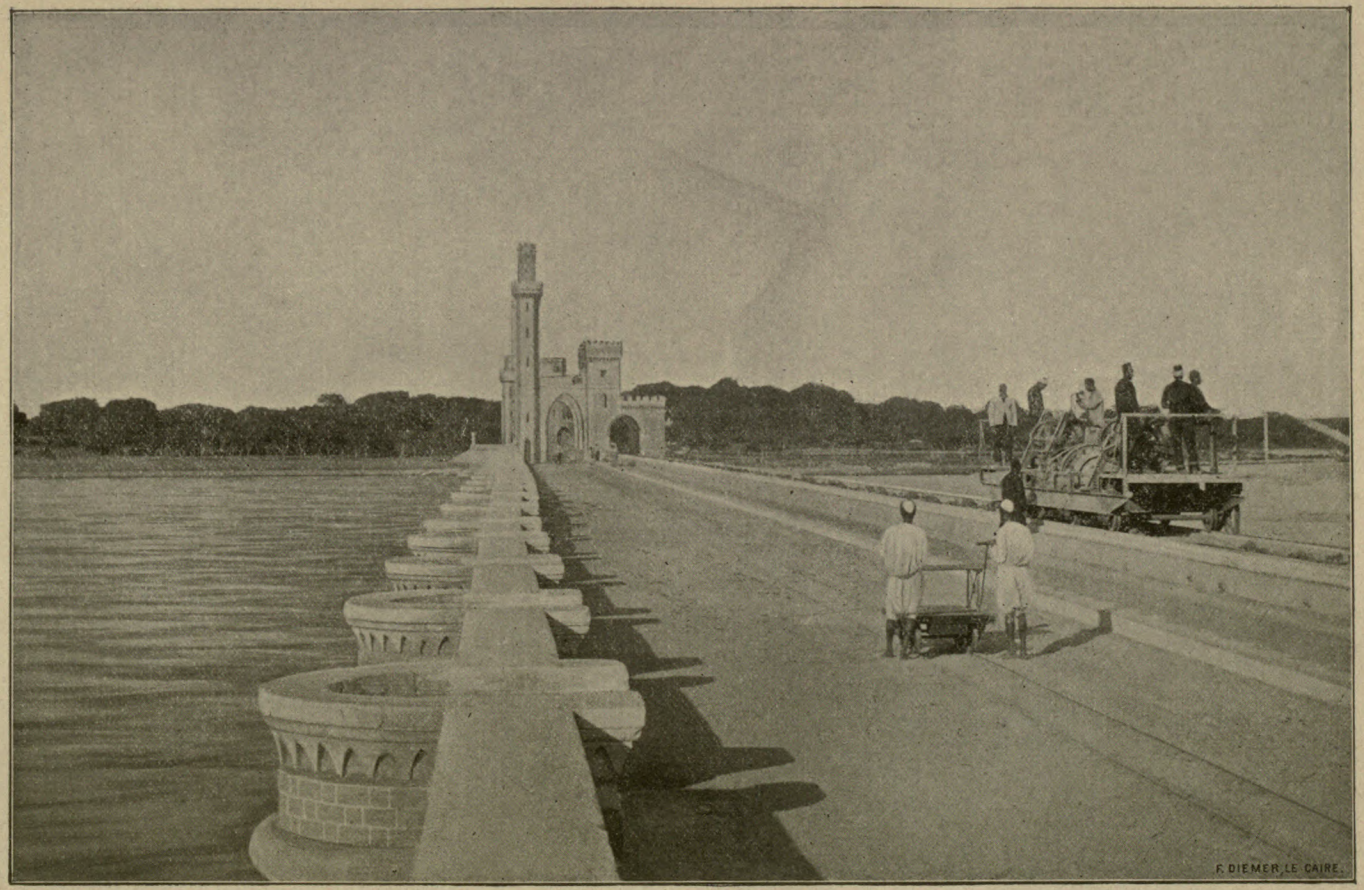

F. DIEMER, LE CAIRE.

Plate III.

View of roadway over the Rosetta Barrage from West end looking East, photographed by Mr. Allan F. Joseph.

This view, which shows the winch for lifting the gates and the tramway that runs from end to end of the Barrages, was photographed to show the displacement of 1867 visible in the line of the parapet wall and more clearly in its shadow.

Barrage in order, but the uncertainty and the expense frightened him. He would not throw good money after bad. He estimated that the sum required to do what was necessary would be 25 million francs, which he remarked as far from being exaggerated, and he calculated that it would take 5 years to do the work. And then he proceeded to make calculations to show that it was preferable to set up steam pumps. This estimate of Linant's should be remembered, when what has been done since and the cost of doing it is read about further on.

In April of the same year, 1871, that M. Linant wrote his note for the Khedive, Messieurs Lavalley and de Langaudin made a joint report, recommending an expenditure of £ 20,000 in repairs to the floors of arches 6 to 13 of the Rosetta Barrage, the repairs to consist of a layer of concrete 3 metres thick laid over the defective floors. This done, the Barrage was to be tested by closing the arches and finding out what head it would stand.

These recommendations were unfavourably criticised in similar terms by both Ali Pasha Moubarek, Minister of Public Instruction and Wakfs, and Bahgat Pasha, Minister of Public Works. The criticisms were accompanied by suggestions more vague and less practical than the proposals under consideration. The two Pashas probably got their heads very close together, when they wrote their separate notes, which however contain nothing worthy of immortality.

Still one more short report was written in 1871 by Mr. D. K. Clark (Engineer representing Mr. J. Fowler). This note contains a well-deserved condemnation of the form of gate adopted and under trial in some of the arches of the Barrage at the time it was written.

Sir John Fowler's Proposals.

The next to be called in consultation to prescribe for the despaired-of patient was a well-known English engineer, Sir John (then Mr.) Fowler. He examined the Barrage in 1876, pronounced the piers and arches, so far as visible, to be of good construction, but the floor to be defective. The floor-surface of brick and stone was not in a bad state, but the concrete below was, in some places being no more than a confused mass of small stones or gravel. He was convinced that the foundations of the floor were too shallow, and that considerable and expensive works were required to put the Barrage into working order, half measures being useless.

Sir John Fowler proposed not to abandon the Barrage entirely, but to utilise the existing work as far as possible, and to obtain the additional height, to which it was desired to raise the water-level, by means of a new and independent construction. He recommended that the gates of the existing Barrage be completed and be made efficient, that a new line of gates be constructed on foundations carried to a great depth immediately down-stream of the existing floor and that the river bed beyond it be protected against scour.

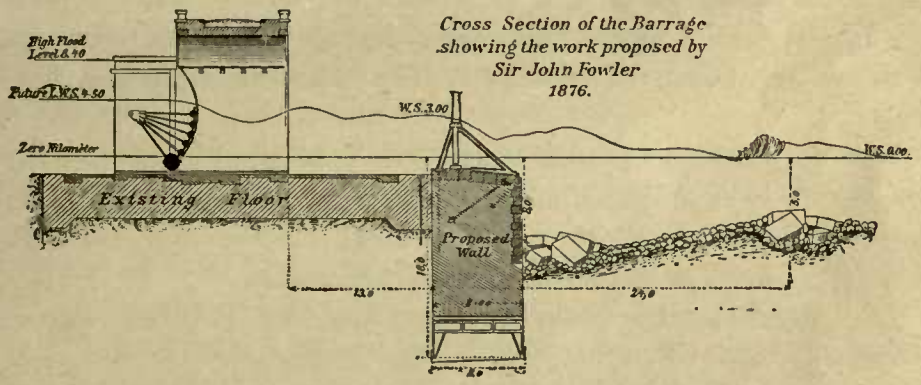
He pointed out that, had not the floor been cracked, the sand of the foundations might have been confined between up- and down-stream curtain walls, and the Barrage have been made to hold up the full 4½ metres desired. But as the floor and foundations were cracked, the sand would have found its way out between the cracks under the pressure of the water and the foundations have been undermined.

As the Barrage had actually supported a head of 1.50 metres, Sir John proposed to utilise it in future to this extent. The remaining 3 metres was to be held up by gates fixed on a massive wall 8 metres thick and 15 metres deep below Low Water-Level. The river bed immediately down-stream of this wall was to be covered by a wide layer of rubble intersected by two rows of heavy concrete blocks 8 metres below Low Water-Level, so as to

obtain a water-cushion of a sufficient depth to deaden the fall of the water. One row was to be up against the curtain wall and the other at a distance of 24 metres from it. Between these rows and beyond the second row was to be a protective layer of loose rubble pitching. The cross section, Plate IV, shows clearly the form of curtain wall proposed.

But the deep wall had to be made without endangering the stability of the existing structure. Sir John proposed to make it in sections of 35 metre lengths by the aid of iron caissons and compressed air, and to unite the different sections by means of end grooves, by which a tight joint could be

PLATE IV.



obtained in an ingenious way, not very easy to describe. On the top of this curtain wall were to be strongly bolted the iron uprights, which were to hold the down-stream row of gates.

The cost of carrying these proposals out, including repairs to the Locks, was estimated at £ 1,000,000 allowing for probable contingencies; or at £ 1,200,000 allowing for all reasonably possible contingencies.

But the Khedive Ismail Pasha, who was a prodigy of a spendthrift in the gratification of his extravagant whims, refused to sanction this outlay

on a work that was all-important to the country, probably because faith in the success of the work was dead.

In his Report Sir J. Fowler also, like M. Linant in 1871, discusses the relative cost of providing for irrigation by the restoration of the Barrage on the one hand and by the establishment of large pumping stations on the other; but, unlike M. Linant's, his figures prove that the pump project would be not only more costly but less efficient.

In the same year that Sir J. Fowler made his Report, another Report was drawn up by a distinguished Anglo-Indian Irrigation Engineer, Lieut: General J. H. Rundall, R. E., formerly Inspector General of Irrigation to the Government of India. His Report is dated 17. May 1876 and was written for the information of H. H. the Khedive. The Report has not been referred to in any of the publications given in the Preface, and yet the manner of restoring the Barrage, as recommended by General Rundall is very nearly that which was actually adopted; and further, the cost of the restoration was correctly estimated.

In this Report General Rundall lays great stress on the necessity of training the river up-stream of the Barrage, so that its currents shall set in proper directions on the two sections of it, and the river-discharge be divided in correct proportions between the two branches.

Discussing the condition of the floor, he gives his opinion as follows: —

"I cannot however but think myself that the great mass of the substructure must still be in a sound condition, otherwise the great superincumbent weight, which it has to support, must have caused a much more serious settlement than even that which has taken place in the left flank of the Rosetta portion."

* * *

"My own opinion is that the original foundations of the Barrage were ample as regards *depth*, provided that they had been faithfully built; but that they were deficient as regards *breadth* and the protection given both on the upper and lower sides of the flooring."

He recommended obtaining breadth principally by extending the flooring and protective rubble aprons, not with the object of preventing springs finding their way below the work, but as a precaution against scour from the rush of water over the floor. General Rundall also does not class the Barrage with the incurables, for he remarks: —

"The conclusion at which I have arrived is that the present Barrage may yet be made perfectly capable of fulfilling the purpose of its original construction."

He based the following recommendations on the understanding that two essential conditions be fulfilled, viz: — that the flooring be laid dry for a thorough examination and previous to its thorough repair: and that the necessary works be undertaken first to restore and afterwards to maintain a proper equilibrium of the river flood.

The works he considered then necessary were: —

1. Repairs of the floor with strong cement masonry, raising its level one metre and covering it with dressed Ashlar blocks.

2. Extension of floor up-stream by an apron 25 metres wide and 3 metres thick, and, in addition, the formation of a curtain wall of masonry wells sunk 8 metres, or to the depth of the existing rough stone.

3. Extension of the floor down-stream by an apron 60 metres wide and 3 metres thick with two curtain walls like the up-stream one.

4. Substitution of needle system of closure for the then existing gates.

He estimated that the repair work would cost £ 400,000, with £ 100,000 added for training the river and changing the gates, — in all £ 500,000.

If the list of works recommended in this Report and their estimated cost is compared with the account of work done and expenditure incurred in the actual operations of restoring the Barrage, it will be seen what a close agreement there is between the two. In the work, as carried out, the curtain walls have been omitted, and the needle system of closure has not been adopted, but the rest of the recommendations have been in principle carried out.

The training of the river above the Barrage was commenced in 1884 and has been continued ever since. A short account of what has been done, illustrated by a map showing what is being aimed at, will be found on p. 126 of the Irrigation Report for 1894.

Read by the light of the experience and knowledge gained since 1875, General Rundall's Report is recognised as being that of an expert, who had sound views of the situation and had formed a correct estimate of the condition of the Barrages.

Official condemnation of the Barrage.

As a final result of all these Commissions and Reports and in spite of some of them, Rousseau Pasha, Director General of Public Works, in his yearly Report of 1883 on Irrigation, pronounced that the Barrage in its existing state could only be used as a distributor of the river discharge between the two branches. To make it fit to serve even this purpose only, he proposed to spend £ 400,000 in raising the floor of the Rosetta Barrage, so as to enable it, with the addition of suitable gates, to hold up a head not exceeding two metres; and to leave the Damietta Barrage alone, merely maintaining it as a bridge for traffic. The irrigation of Lower Egypt he proposed to provide for by a system of pumping stations.

Having made up his mind in favour of pumps, Rousseau Pasha stated the objections against the Barrage project. The first objection was the cost of restoring or repairing it. This has since been carried out successfully for both Barrages at a cost of LE. 465,000, so this objection has been answered.

The second objection was that he considered that the utilisation of the Barrage would affect the régime of the Nile inconveniently and cause immense deposits up-stream of it. This objection has also been answered by experience showing that what Rousseau Pasha feared does not take place.

The third objection was that it would not only be necessary to restore the Barrage, but to remodel the whole canal system at great expense. This remodelling has since been carried out at a moderate expenditure.

The fourth objection was that the country would be dependent on one work. This is only an objection when the work can *not* be depended on.

The fifth and last objection was that the high level, at which the water would be maintained, would cause damage to land from infiltration. This objection experience has shown to be a real one, but it applies with far greater force to the system of irrigation by pumping, as it was claimed in support of this system that it would deliver water onto the surface of the land without any further lifting on the part of the cultivator.

But as experience and accomplished facts had not disposed of these objections in 1883, the Barrage stood condemned in an official document to play a minor part in the irrigation of Lower Egypt to that for which it was originally designed.

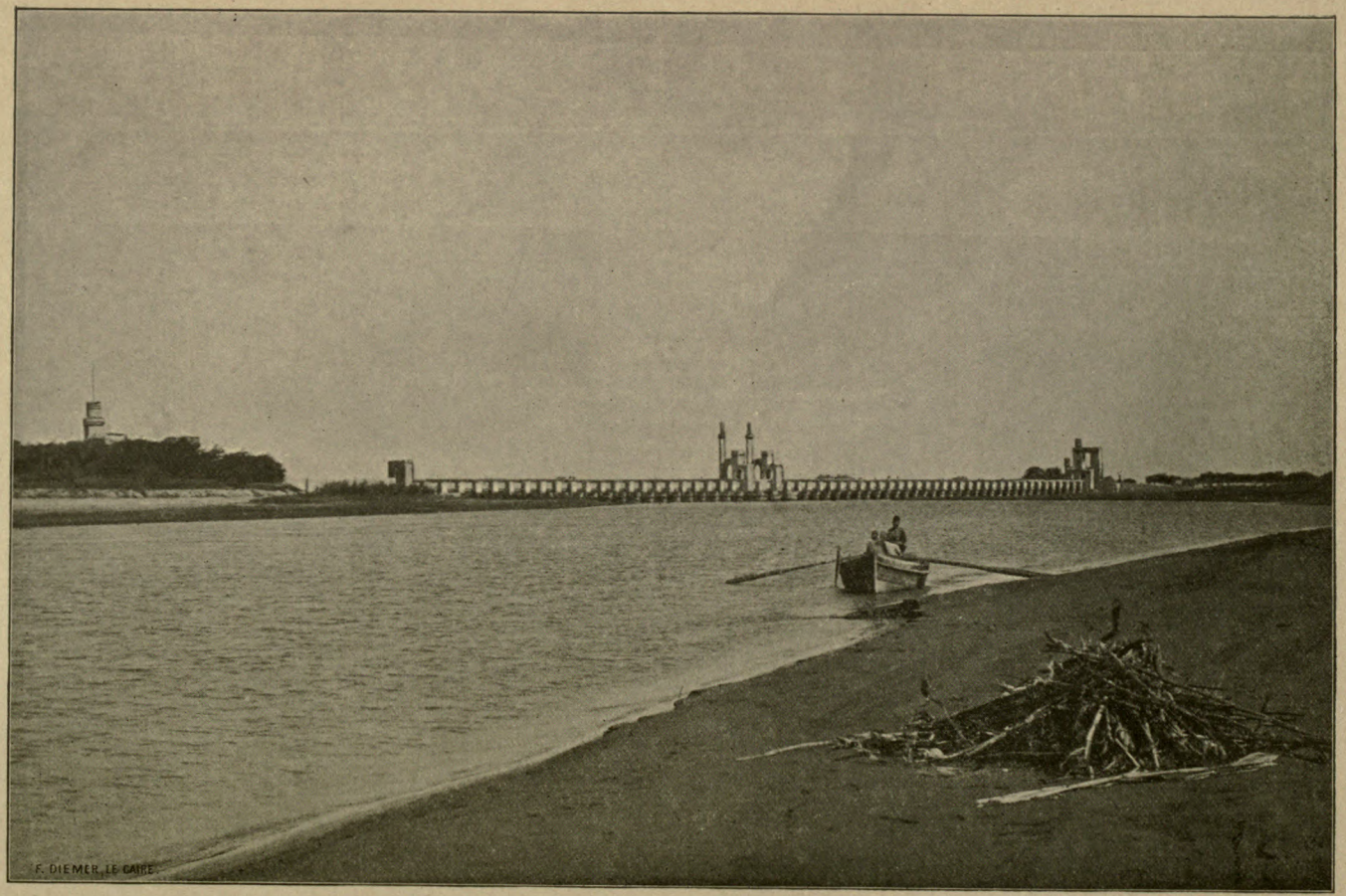

F. DIEMER, LE CAIRE

Plate V.

View of the Damietta Barrage up-stream from the cross channel connecting the two Barrages,
photographed by M. Allan F. Joseph.

The arches, that are hidden from view between the left-hand flagstaff tower and the low square tower are those, which were closed during the restoration.

The central towers were built for a lift bridge, as it was originally intended to have a navigation opening in the centre, but this passage was suppressed and converted into two openings. The same arrangement will be remarked in the Rosetta Barrage.

CHAPTER II.

Object and description of the Barrage.

The object of the Barrage, as has been stated in the previous Chapter, is to raise the river level to a convenient height for the irrigation of the Delta. The two branches of the Nile divide the Delta into three separate divisions; the Barrage consists of Regulators built across each branch of the Nile at the apex of the Delta, and the irrigation of the three divisions is provided for by three main canals fed from the high-level water above the Barrage. (See Plate VI.) The West division is the Province of Beherah and is irrigated by the Rayyah Beherah; the central division comprises the Menufiyah and Gharbiyah Provinces and is irrigated by the Rayyah Menufiyah; and the East division, comprising the Provinces of Kalinbiyah, Sharkiyah and Dakahliyah is irrigated by the Rayyah Tewfiki (made in 1889), assisted by the canals Ismailiyah, Sharkawiyah and Basusiyah. These last three canals take off from the right bank of the Nile between Cairo and the Barrage, and are also affected by the regulation of the river level at the Barrage: they provide irrigation for the Province of Kaliubiyah and the greater part of Sharkiyah.

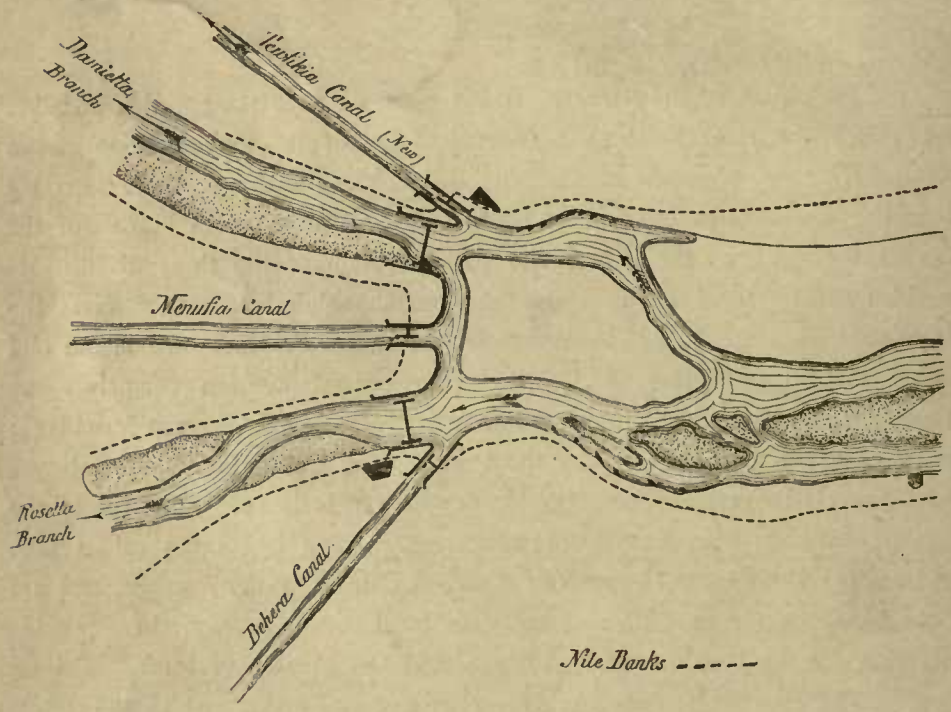
The Rosetta Barrage has 61 arches and two locks, and is 465 metres long between the flanks: the Damietta Barrage had originally 71 arches (since reduced to 61) and two locks, and was 535 metres long.

The Barrages, according to the originally accepted design, had respectively 72 and 62 arches, and also a navigable opening in the centre

of each Barrage 14.50 metres in width, which it was intended to leave always open. These navigable openings were converted into two arches, each of 5.50 metres span, and the place of 3 end arches was occupied by a lock

PLATE VI.

General Plan of Nile Barrage



constructed on that flank where no lock had been provided in the original design. The two Barrages are separated by a revetment wall about 1000 metres in length, in the middle of which is situated the head of the Rayyah

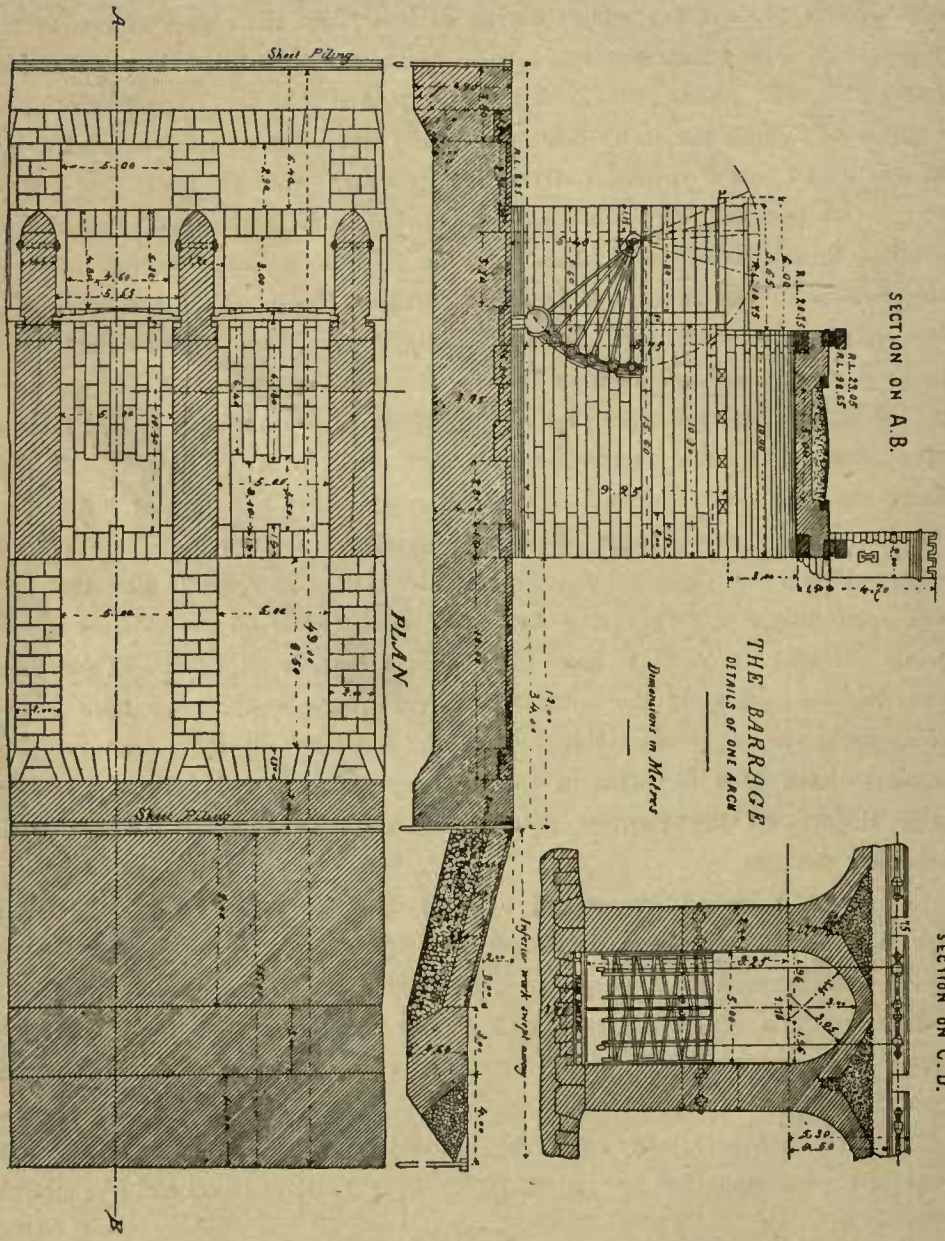
Menufiyah. The arches of the Barrages are all of 5 metres span, except the two in the centre, which are 5.50 metres. They are fitted with gates, which are used to close the openings during summer with the object of raising the water-level, but which are lifted clear of the water in flood to allow a free passage for the river. It was originally intended that the Barrage should be capable of raising the water-level, when the river was at its lowest, by $4^1/_2$ metres or 14 feet 9 inches, but this it was never equal to doing.

A peculiar feature of the Barrage, before its restoration, was an iron grating, 30 centimetres high, fixed into the piers across each opening between the bottom of the gates and the floor surface. These gratings allowed of a free passage of water when the gates were down. They were originally put in to prevent deposit of mud in front of the gates when shut. The gratings on the Rosetta Barrage were capable of discharging, with a head of 1.75 metres, over 20,000,000 cubic metres per day, according to Mr. Willcocks. It was found that the severe action below the Barrage, when a gate was lowered to its full extent, was due to these iron gratings, and not, as it had been supposed, to a honey-combed foundation. Mr. Willcocks remarks that this fact was apparently unknown to the writers of the Reports on the Barrages, and points out that, it ought to have been evident that, if all the action observed was due to fissures in the foundation, the Barrage would have been swept away many years before. But though the existence of these iron gratings seems to have been forgotten in 1884, it was not so in 1871, for M. Lavalley in a Report on the Barrage dated 10th April 1871 refers them in the following passage: —

"Enfin les ouvertures qui existent dans les seuils en fonte devront être bouchées. Les pertes d'eau qui se feraient par ces seuils sont telles, qu'elles ne permettraient même pas d'atteindre à l'étiage une charge d'eau d'un mètre. La dénivellation de 1.75 m. qui a été constatée était due sans doute à la hauteur du Nil à ce moment et à ce qu'un certain nombre d'ouvertures étaient déja obstruées."

Another peculiarity was the original form of iron gate with which some of the openings had been fitted. They were 5 metres broad and $5^1/_2$ metres

PLATE VII.


A
B
Sheet Piling
Sheet Piling
PLAN
SECTION ON A.B.
THE BARRAGE
DETAILS OF ONE ARCH
Dimensions in Metres
SECTION ON C.D.

high, shaped as the arc of a circle, and supported at either end by iron rods radiating from the arc to the centre; here they were attached to massive iron collars working round cast-iron pivots embedded in the masonry of the piers at the centres of the arcs. It was originally intended to lower the gates by their own weight, and to raise them by compressed air automatically pumped into the hollow ribs, but the principle did not work. These gates have been replaced since 1884 by more simple and more efficient ones, and the hollow ribs of the original gates may now be seen scattered about the country, serving as land boundary pillars and kilometre-posts. These old gates are to be seen in Plate X still in place.

The new system of regulation adopted in the restored Barrage consists of wrought iron gates provided with rollers sliding in cast-iron grooves fixed in the piers. Since the maximum depth of water on the floor is 4 1/2 metres (14 1/2 feet), each opening has been given double grooves and two gates, of which the upper one is always 2 1/2 metres high, and the lower one in the Damietta Barrage 2 metres. In the Rosetta Barrage the height of the bottom gate varies from 2 1/2 to 1 metre in height on account of the floor having been raised to different levels during the repairs. In one arch, No. 9, there is no bottom gate at all, the floor level being at R. L. 11.50. The top of the upper gates, when the Barrage is closed, is at R. L. 14.00, and of the lower gates at R. L. 11.50 throughout. The floor of the Damietta Barrage is at R. L. 9.50 in every archway: that of the Rosetta Barrage varies in different arches from R. L. 11.50 to 9.00.

The gates are lowered and raised by means of powerful crab winches (of which there are two to each Barrage) travelling on continuous rails.

Plate VII from "Egyptian Irrigation" by Willcocks, gives details of the Barrage as originally built, or intended to have been built. Plate VIII gives a typical cross section of the Barrage after restoration, without showing the recently formed clay apron up-stream. For record sake I give below the varying levels of the floor on the Rosetta Barrage.

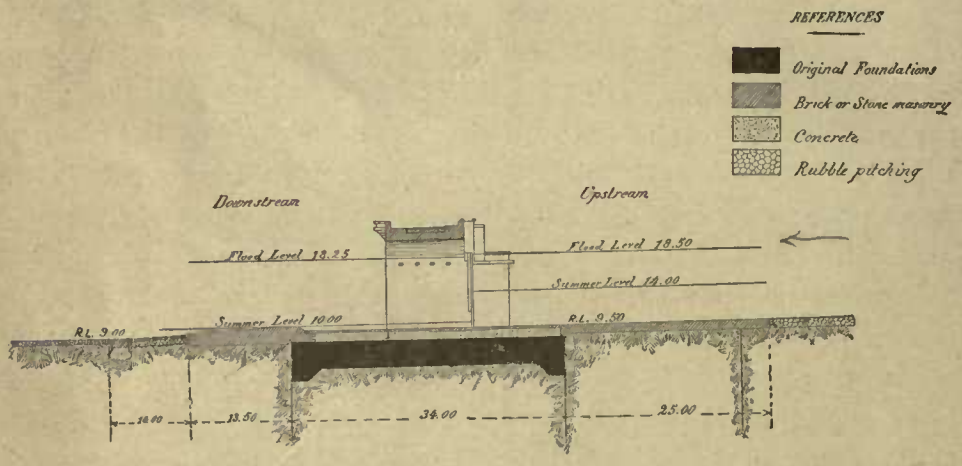
At R. L. 9.00. No. 19 to 22, 24 to 25, 27 to 45, 55 to 61.
R. L. 9.20. No. 46 to 54.
R. L. 9.50. No. 1 to 6, 12 to 18, 23 and 26.

R. L. 10.00. No. 7 and 11.
R. L. 10.50. No. 8 and 10.
R. L. 11.50. No. 9.

The arches, throughout this Note, are numbered from West to East.

PLATE VIII.

BARRAGE TYPE SECTION



In Chapter I. it was shown that the East half of the Rosetta Barrage was founded on a mass of rubble stone tipped into the water to fill up the deep channel of the river. In several of the Reports on the Barrage a fear was expressed that when it was subjected to a head of water, a flow would take place through the unfilled interstices of the rubble heap. This however does not now at any rate take place, as the Nile deposit has staunched this mass of loose stone and it is not improbable that this section of the Barrage is now the most secure portion of the whole construction.

CHAPTER III.

History of the Barrage from the year 1884.

Verdict of Condemnation re-considered.

A new period in the history of Egyptian irrigation began in May 1883, when Sir Colin (then Colonel) Scott Moncrieff came to Egypt and the Irrigation Department and Works were entrusted to him to be put in order with the satisfactory results recorded in various publications since that date. But this account is concerned with the Barrage alone and the temptation to digress and tell of what the Department, organised by Sir Colin, has done, must be resisted.

The Public Works Ministry had just concluded a contract, to last until 1915, with a private Company to supply irrigation to the Western Delta at a cost of about £. 50,000 per annum; and the first thing Sir Colin had to do was to pronounce on a proposal to extend the application of this system of irrigation by means of pumps to the whole of Lower Egypt at an initial cost of £. 700,000 and an annual outlay of £. 248,550.

Hitherto there had been differences of opinion as to the relative merits of the two systems of providing for the irrigation of the Delta — by means of the Barrage, or by pumping. But, at the time of Sir Colin's arrival, unanimity seems to have been established, and all, English as well as foreign

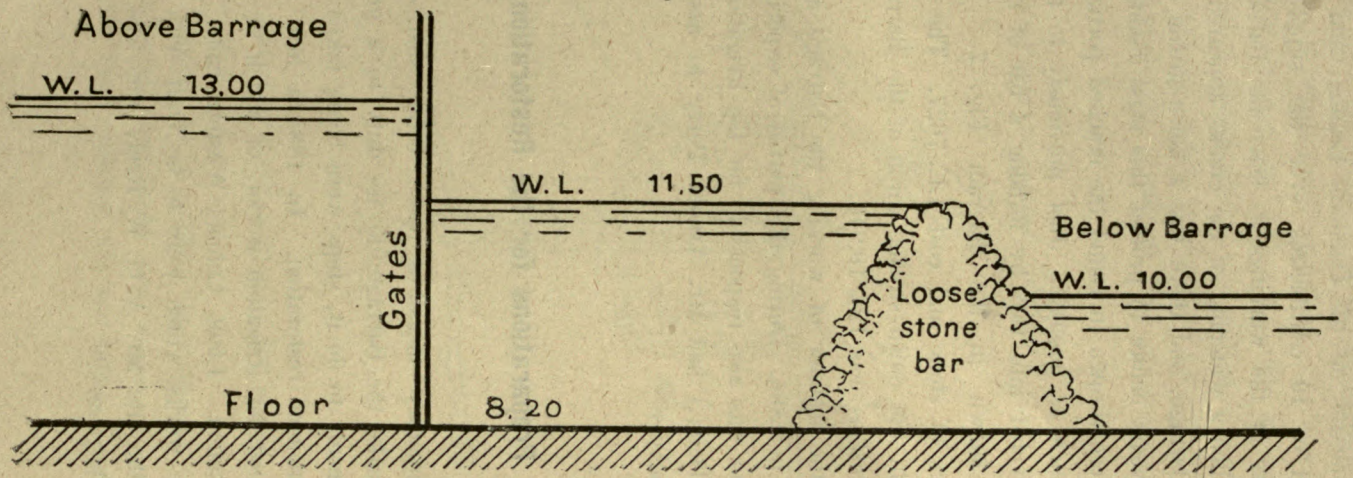
engineers, warned him to have nothing to do with that unsound work. Sir Colin, however, with his Indian experience to influence him, was not satisfied with the soundness of these conclusions, and, before accepting the extravagant programme of pumping stations, he felt that he must be certain that the Barrage was the worthless failure it was represented to be.

In December 1883 therefore, when Mr. Willcocks came from India to join the Egyptian Irrigation Service, Sir Colin stationed him at the Barrage to apply his enthusiasm and recognised ability to the task of testing the work and determining what it could be called upon to do. Mr. Willcocks found the closing apparatus in very bad order, the staff, though large, quite incapable of doing anything beyond drawing their pay, and appliances and tools almost entirely wanting: the stone pitching below the Barrages had never been completed and the Damietta Branch had no gates at all. Mr. Willcocks set to work to remedy or remove these defects, expending L. E. 25,611 in so doing during 1884. As the river fell, first one and then the other Barrage was closed, this being the first time that the Damietta Barrage had ever been regulated on at all. The result of these operations was that, in June 1884, 2.20 metres (7 feet 2 ins) of water was being held up on the Rosetta Barrage and about 0.95 on the Damietta, obtaining thereby a command of water of about one metre more than the average, which, however, was due in part to a favourable summer Nile. Not only was an abundant supply of water thus obtained for all the lands irrigated by the Delta Canals, but the water was delivered at a higher level, and such enormous savings in canal clearances were effected that the idea of abolishing the Corvée wes entertained for the first time.

Previous to 1884, the cotton crop had given the greatest outturn in 1879, when the Nile at Aswan at its lowest was 1.39 metres higher than in 1884. The outturn in 1879 was 3,186,060 kantars or cwt; in 1884 it was 3,630,000 kantars. The result, therefore, of the first year's experiment was satisfactory and encouraging.

In 1885 the summer Nile was a low one. But the Barrage was this year made to hold up as much as 3 metres (9 feet 10 ins) on the Rosetta.

Fig. 7


Above Barrage
W. L. 13.00
W. L. 11.50
Gates
Below Barrage
W. L. 10.00
Loose stone bar
Floor
8.20

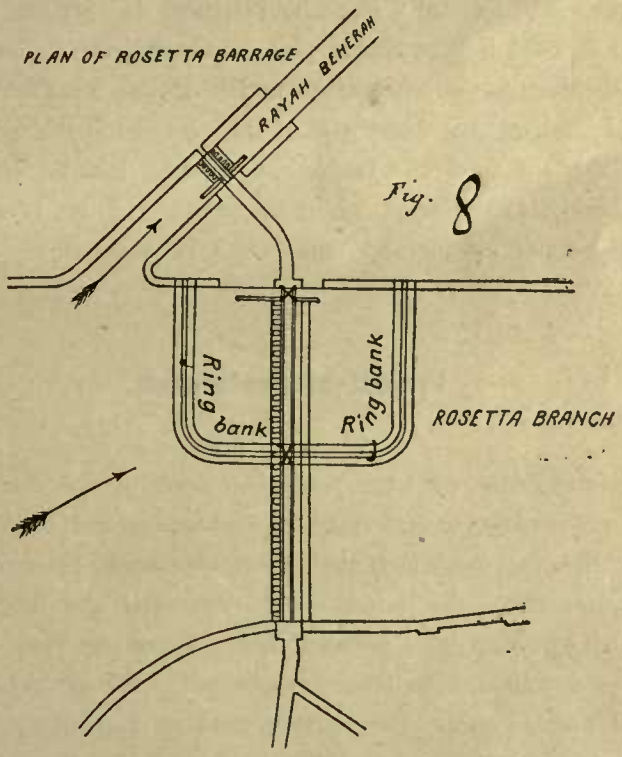
Branch and 1.76 metres on the Damietta Branch, and this gave the canals an increased level of 10 centimetres over the supply of 1884. But an unpleasant reminder of the warnings to leave the Barrage alone occurred on the 21st March, when a widening of the cracks appeared in arches No. 7 and 8 of the Rosetta Barrage, and there was a down-stream subsidence of the old coffer-dam put in years before to protect this most doubtful part of the work. Masses of stone were thrown in round the cracked portion, so as to take the strain off it as much as possible. Just previously to this the head on the work had been divided into two by forming a bar of rubble on the floor of the Barrage as shown in the diagram Fig. 7. This bar contained 26,100 cubic metres of stone and cost LE. 7627. The bar was removed in July and utilised in the down-stream apron of the Barrage. The sum spent on this year's operations was LE. 18,246.

In 1886 the manner of working the Barrage and the results were much the same as in 1885. During this period of experiments, 1884 to 1886, Mr. Willcocks, (who was also responsible for the irrigation of the two Central Provinces of the Delta,) had Mr. Arnold Perry to assist him as Resident Engineer at the Barrage.

Preparations for the Restoration.

While temporary measures were being successfully employed by Mr. Willcocks to make the Barrage do its duty to a greater extent than it had hitherto been made to do it, steps were being taken to provide ways and means for its permanent restoration. In 1885 a loan of a million pounds sterling was obtained for irrigation works, of which the most important was the Barrage Restoration. Lieut. Colonel Western came the same year from India to direct the works which were to be built with the Million, and he brought with him the late Mr. A. G. W. Reid, who was afterwards specially charged with the Barrage.

Before describing what was done to the Barrage, it will be as well to explain what system it was decided to adopt. As a result of Mr. Willcocks experiments with the Barrage in 1884 and 1885, it was resolved first that the irrigation of Lower Egypt should be carried out on the general scheme laid down by Mehemet Ali, which consisted in raising the Nile level by means of Regulators and producing a natural flow of water into the canals. The



rival proposition to raise the water artificially by pumping from the river into the canals was rejected.

The next question to be settled was: Should the Barrage itself be repaired and strengthened, or should new works be constructed to do the work the Barrage had been designed but had hitherto failed to do?

For some time after their arrival Colonel Western and M. Reid thought the task of restoring the existing Barrage so unpromising that they were inclined to favour an entirely new work, and estimates were framed accordingly. But after some hesitation and the examination of alternative proposals, it was finally decided not to abandon the old Barrage, if it were found possible to repair it. To settle this point, it was considered necessary to get down to the floor and find out its actual condition; which was not so easy to do under the $4^1/_2$ metres ($15^1/_2$ feet) of water which covered it. Still this was successfully accomplished in 1886 by the simple plan of forming earth banks above, below and across the Barrage to enclose 20 arches at the West end of the Rosetta Barrage, and pumping the water out of the enclosed space. Within this space the bed of the Nile and the Barrage floor were laid dry without excessive pumping, although they were about 5 metres (16 or 17 feet) below the surface of the water outside the banks not fifty yards off — See Fig. 8.

Project of Restoration.

In consequence of what was then seen of the foundations of the Barrage, it was decided to undertake its restoration, and it therefore remained to lay down the lines on which the restoration should be carried out. Under a head of water there was danger of the fine sand and mud, on which the Barrage, as constructed, was founded, being forced out from under the floor, and of the work failing from being undermined. The problem then requiring solution was how to make the Barrage into an impermeable bar across the river, under which water, acting with the force due to the head it was desired to maintain, should not be able to make its way.

Sir John Fowler's proposal of a deep and massive down-stream curtain wall was rejected on account of the difficulty of building it, its great cost and the danger of bringing down the Barrage in the process of sinking the wall. As deep excavations in the neighbourhood of the existing work were

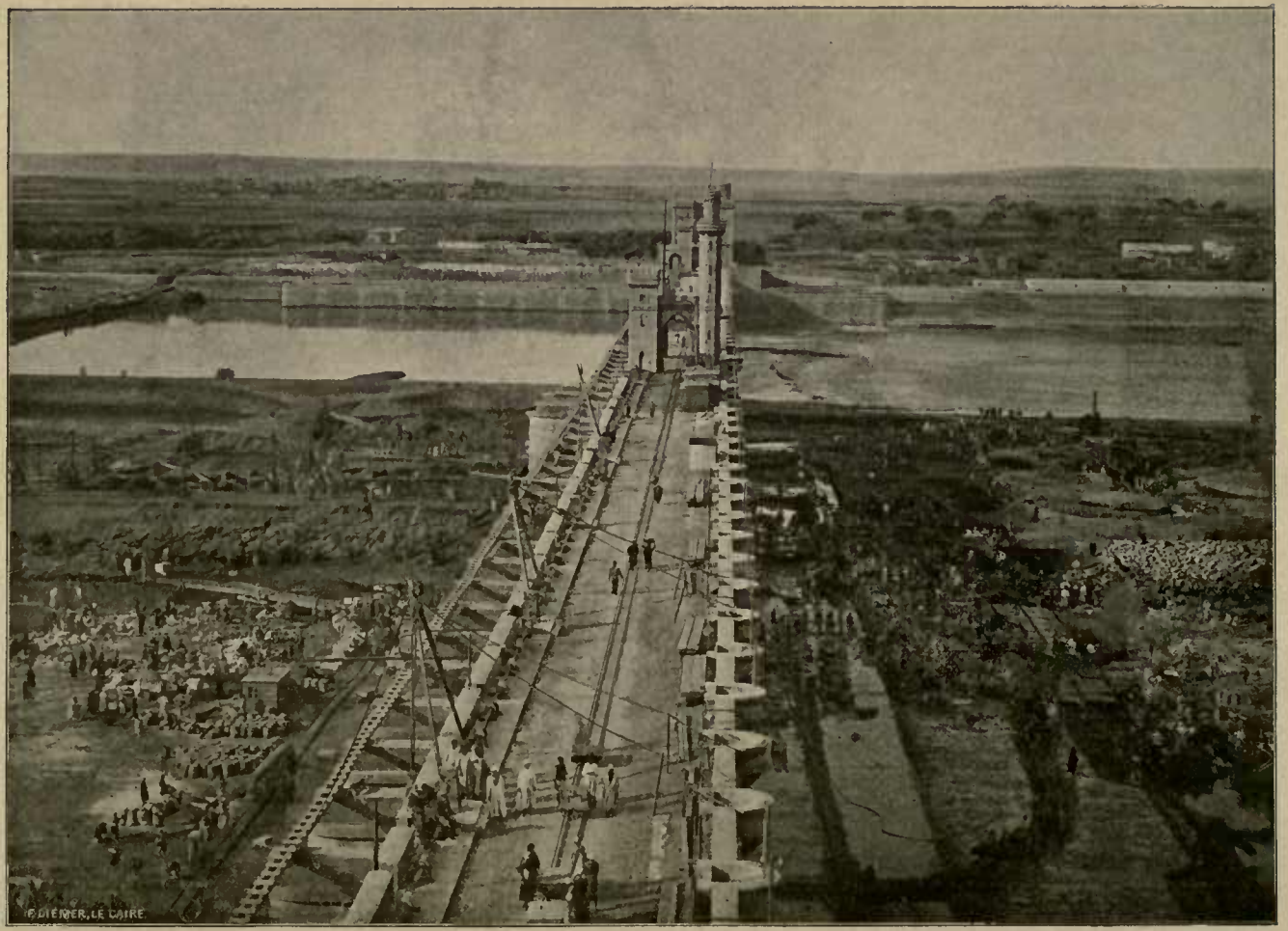

P. DIEMER, LE CAIRE

Plate IX.

View of the Rosetta Barrage during the third season's work of restoration, looking West,

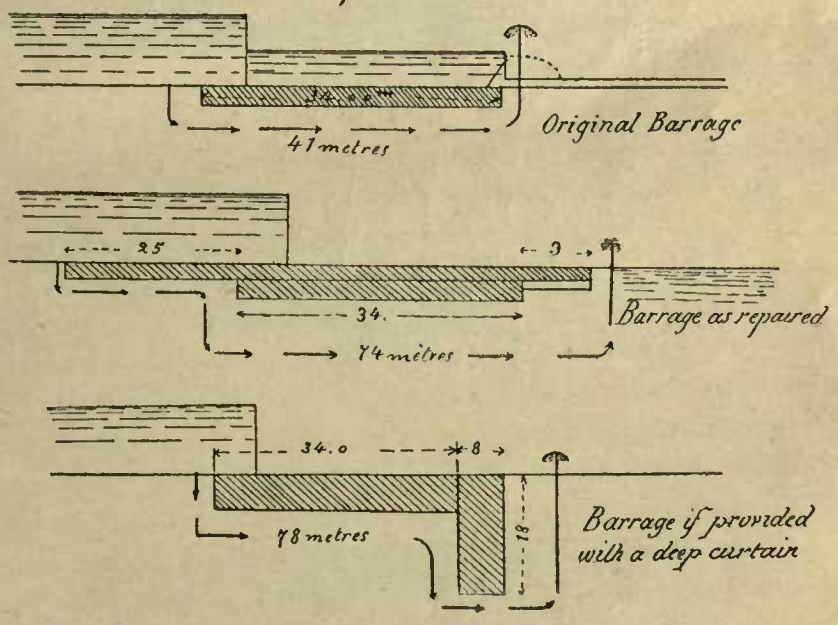
photographed by M. J. Heyman.

This view shows the raised floors of the West end repaired during the first season's work. A bridge of boats connects the West side with the bank, enclosing the East end of the Barrage, for the transport of materials.

considered dangerous Colonel Western decided, in preference to constructing deep curtain walls, to spread the foundations out horizontally, so as to form a broad water-tight platform.

"By an extension of the floor up and down-stream, the points, at which water enters the strata under the Barrage floor from the upstream side and issues as springs on the down-stream side, are placed so far apart, that the

Fig. 9



resistance the water will meet with on this length will be sufficient to deprive it of the force necessary to move sand and carry it away from under the work. The springs will issue clear and be harmless. The figures above (Fig. 9) explain the action of the springs and the distance they have to travel". (Willcocks.) —

But besides adding to the width, it was necessary to give additional security to the old work. This was to be done by covering the existing floor with a layer of Portland cement concrete 1.25 metres (4 feet) thick, over which was to be laid a heavy pavement of dressed Trieste Ashlar stone under the arches and over the down-stream apron, where the action was most severe. The floor was to be extended up-stream 25 metres in rubble limestone masonry.

Fig. 10

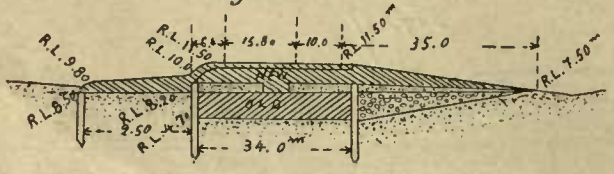


Fig. 11

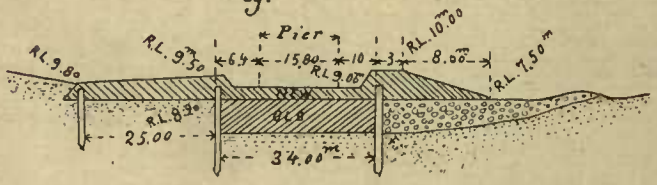
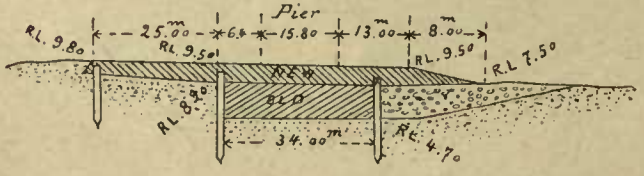


Fig. 12



Along the up-stream edge of this extension a line of sheet piling, 5 metres (16 feet) deep, was to be carried across the whole river.

This programme was generally carried out, but where special difficulties were met with, the new flooring often exceeded 2 metres (6½ feet) in

thickness. See Figures 10 to 12, which show by typical cross sections how the work was actually executed. The difficulties of the work were much increased by the necessity of using the Barrage to hold up water for irrigation all the time work was going on, the strength of the springs to be dealt with being thereby greatly increased. Sir Colin compared the operations to mending a watch without stopping the works. The working season, moreover, between two floods was short, and in the most favourable year extended only from the 1st November to the end of June. More than two months of this period was expended in forming the ring banks and nearly as much in pumping out the enclosure and making other preparations. Only four months were left for actual work on the floor, which could not generally be begun before the 1st March.

Preliminary season 1886.

It has been already stated that in 1886 twenty arches of the Rosetta Barrage were enclosed and laid dry for the purpose of examining the floor in this, the worst section of the Barrages, with the view of enabling a final decision to be taken as to the general restoration; and that, as a result of the examination, the restoration was decided on. Advantage was taken of this opportunity to partially repair the floor under six of the arches.

As the whole discharge of one branch of the river could not be shut off at a time, it was arranged to spread the work of restoration over four seasons, half of one Barrage being taken in hand at a time.

Sir Colin, in his "Note on the Nile Barrage, 1890", shortly describes the four seasons work and the following account is taken almost verbalim from his Note. A more detailed account will be found in Mr. Reid's Reports and an abridgment of the late Liernur Bey's Report, published in the Irrigation Reports for 1887, 1888, 1889 and 1890.

Season 1887.

Work began in earnest in 1887, when the Western half of the Rosetta Barrage was undertaken. The first season was the worst of the four. Experience of what was to be done was less and appliances more incomplete than in succeeding seasons, and the section of the Barrage taken in hand was in much worse condition than any other.

On the 2nd December 1886 the enclosing earth dams were begun: on the 24th March 1887 the first stone of the new work was laid. From the latter date

work was carried on day and night, electric light being used during the night, while nine powerful steam pumps were constantly at work keeping down the water, until, in anticipation of the arrival of the flood, the last piece of machinery was removed from the completed floor on the 1st July. Before the next morning the rising flood had covered all that had been done.

During the course of the season's work fresh and unlooked for difficulties were experienced every day. A serious difficulty arose in connection with the Western Lock. It was found that the massive outer wall of the Lock rested on foundations, the base of which was 8 feet higher than the Barrage floor. To dry the latter, work had to go on below the Lock foundations, and these foundations were appallingly bad as described by Mr. Reid in his Report. It was only with difficulty that the Lock wall was prevented from falling over bodily.

In the Barrage itself it was found that the floor, as well as the arch of one opening, was cracked across diagonally, showing a complete fracture of the work, the fissure being 4 inches wide. Strong springs burst out daily in fresh places, and had to be staunched at an immense expenditure of material. Daily Mr. Reid had to face some new trouble and to invent some new expedient, and he was always equal to the occasion. The result of the season's work was satisfactory, and established confidence in the ultimate success of the restoration.

Season 1888.

In 1888 the Eastern half of the Damietta Barrage was attacked, and the work proved to be easier than that of the preceding season. The earthen dams were begun on the 1st December 1887, and the repairs to the floor on the 9th March. The condition of this Barrage was much better than that of the other, but it seemed that this was so, only because the work had been less tried. There was the same inferior and careless work. The floors of some of the arches were quite unfinished, and if the gates had ever been put in place and subjected to pressure, the effect must have been as disastrous as in the case of the Rosetta Barrage. By the 20th June, when this season's work came to an end, 41 arches had been put in order.

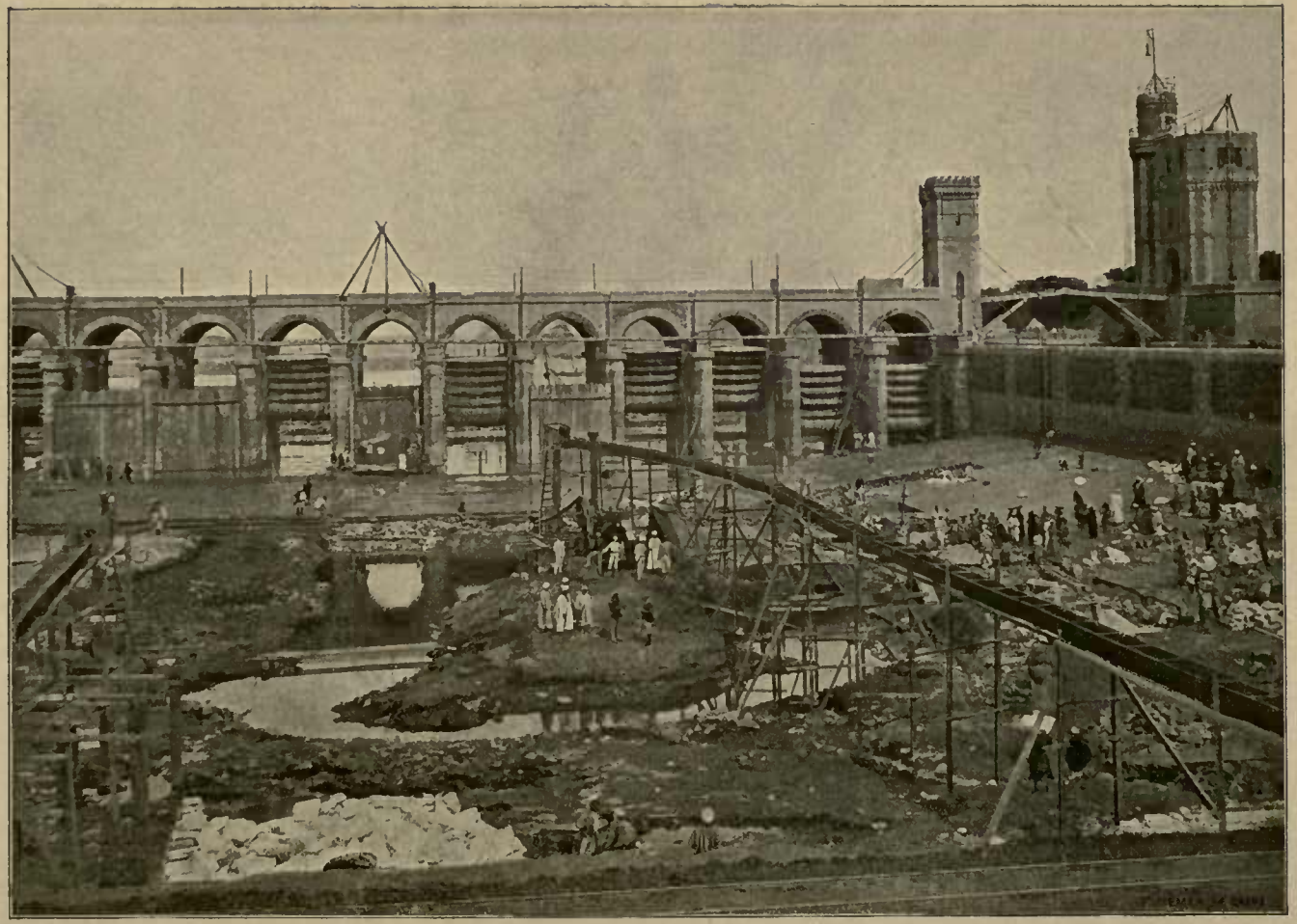


Plate X.

View of the East end of the Rosetta Barrage during restoration, photographed from the up-stream enclosing bank by M. J. Heyman.

This view shows the old form of gates, and the sloping addition to the Barrage floor added to secure the stability of the Lock wall.

After the deficient flood of 1888 the river fell fast, and as early as the 2nd November the earth dams were begun to enclose the Eastern half of the Rosetta Barrage, which still remained to be repaired. This was the section of the Barrage, which had been built on a mass of loose rubble. It was a fortunate thing that the dams could be begun so early, as they had to be formed in water which, over a length of 100 yards, averaged 40 feet in depth. This season's work was the easiest and least eventful of all, and was completed in good time in June 1889. Plates IX. and X. are photographs of this season's work, taken by M. J. Heyman, Photographer, Cairo. Season 1889.

In November 1889 the last season's work began. It was expected to be a very easy one, but proved otherwise. There did not appear to be very much to do, since, of the 71 arches of the Damietta Barrage, 41 were already finished, and it had been resolved to cut off and close the 10 arches together with the lock at the West end of the Barrage, as it was found that the extra waterway, provided by them, was in excess of what was necessary or even desirable. There were only 20 arches then to repair, and the work seemed advancing very fast, when suddenly a powerful spring burst out in the half-repaired floor, and it was found that a rush of water was finding its way from the river outside, 230 feet distant, under a portion of the new flooring laid in 1888. This spring, throwing up mud and sand, soon drowned out the pumps. Mr. Reid promptly cut his enclosure banks and flooded the whole area. The action of the stream had washed out the treacherous soil below the new upstream apron and a considerable portion had settled as much as four feet. Mr. Reid then threw up new banks, so as to isolate the unsound parts, and, little by little, with great precaution and frequent checks, he repaired all the mischief. Season 1890.

On the 16th June 1890 he reported that the Barrage below water-level was finished. Four season's anxious work was at an end, and the Barrage was pronounced to be capable of holding up 4 metres of water. The work was then placed under Mr. E. W. P. Foster, with M. Liernur as resident engineer. It will be pointed out further on what it has actually done.

Cost. The total cost of this restoration for both Barrages was LE. 465,000.

The quantities of masonry executed were: —

Concrete	23,863	cubic metres
Rubble masonry . .	54,411	„ „
Ashlar masonry . .	6,983	„ „
Brick masonry . . .	2,680	„ „
Dry rubble pitching .	25,460	„ „
Total of all sorts	113,397	cubic metres.

CHAPTER IV.

Work done by the Barrage.

Effect on the river level above the Barrage obtained by regulation on it before and after its restoration.

To enable a comparison to be made between the effect produced by the Barrage before and after its restoration, it will be useful to give an account of the manner in which the Barrages were regulated previous to 1884. This account is taken from "Egyptian Irrigation" (Willcocks).

"When the Nile gauge stood at R.L. 12.50 metres, which generally happened in March, the Rosetta Barrage gates and needles were quickly lowered to their full extent, beginning at opening No. 61 (East end) and closing at No. 1 (West end). The consequence was a rapid current through the last openings just before they were closed. It was on one of these occasions that the 10 openings from No. 5 to No. 14 were injured, according to the report of the Egyptian foreman on the work. The Government Report states that they were injured during the floods of 1867 owing to contracted waterway. As soon as the gates and needles reached the gratings, they could descend no further, and the work of regulation was at an end for that year. The up-stream gauge rose to R.L. 13.00 metres, while the down-stream gauge fell to R.L. 11.25 metres; so that, with a difference in water surface of

1.75 metres, there was a gain in water-level of only half a metre. This was due to the fact that the Damietta Barrage was open. Of the water, which escaped through the Rosetta Barrage, practically the whole found its way through the iron gratings. These gratings, with a head of 1.75 metres, were capable of discharging over 20,000,000 cubic metres per day. The river kept falling through April, May and June, and during the whole of this time the Damietta Barrage was open, as well as the gratings of the Rosetta Barrage. There was not sufficient water in the Nile to allow of a head of 1.75 metres on the latter, and it fell to 1.00 metre. Towards the end of June the up- and down-stream gauges roughly indicated 12 metres and 11 metres respectively. If the Rosetta Barrage had failed in June, the loss of head in the Delta canals would have been 35 centimetres. When the Nile began to rise in July and the up-stream gauge read R. L. 13 metres, the gates were raised as quickly as possible, the river fell to R. L. 12.50 metres, and was allowed to recover as the flood rose. This it generally did in six or eight days."

Thus, previous to 1884, the maximum head held up by the Rosetta Barrage was 1.75, decreasing to 1.00 at the time of lowest Nile, and the water-level maintained above the Barrage was at R. L. 13.00, decreasing to R. L. 12.00 in June. The Damietta Barrage was always open and held up nothing.

From 1884 to 1886 inclusive, Mr. Willcocks was in charge of the Barrage. In 1884, in consequence of additions to the rubble talus and improvements made in the closing arrangements of both openings and gratings, the Rosetta Barrage was made to support a maximum head of 2.21 metres, and to maintain an up-stream water-level of R. L. 13.00 almost throughout the period of Low Nile. The Damietta Barrage held up a maximum head of 0.95 metre.

From 1885 to 1890 inclusive the upstream summer level was kept, with but slight variations, at R. L. 13.00, the maximum head on the Rosetta Barrage varying from 3.00 metres in 1885 to 3.43 metres in 1890. On the Damietta Barrage the maximum head varied during this period from 1.76 metres in 1885 to 3.26 metres in 1890.

After 1890, the year in which the Barrage restoration was completed, the levels maintained above the Barrage varied from R.L. 13.50 in April and May to R.L. 14.00 in July, the maximum head held up at any time having been 4.07 metres on the Rosetta Barrage and 3.72 on the Damietta.

To show the results in a convenient form for comparison the following table is given: —

PERIOD	MAXIMUM HEAD HELD UP		UPSTREAM LEVEL in June
	Rosetta	Damietta	
			R. L.
Previous to 1884	1.76	nil	12.00
1884 to 1886	3.05	1.76	12.90 to 13.00
1887 to 1890	3.43	3.26	12.90 to 13.00
1891 to 1895	4.07	3.72	13.75

The up-stream level in June could now, if desired, be kept up to R.L. 14.00, except in very low summer Niles, but it is thought better to keep the level down, so that cultivators may not be encouraged to put under crop more than there will be water for at the time of shortest supply. The up-stream level is, therefore, not brought up to R.L. 14.00 until July when the demand for water becomes greatest.

In 1892 the up-stream level in June fell to R.L. 13.22, the lowest level reached in summer since 1890. This was not because the Barrage could not hold up more, but because there was so small a discharge in the river, that the draw of the canals, taking off from above the Barrage, kept the water surface up-stream of it down. In the summer of 1892 the Barrage gates were caulked with rags to stop leakage and every drop of water in the river was turned into the canals. The Barrage could not do more.

Damietta Barrage Springs.

But the levels, maintained since the Barrage restoration, were not obtained without some anxiety being produced. In May 1891, when the Damietta Barrage was holding up 3.18 metres of water, 7 springs appeared along the down-stream edge of the masonry floor opposite bays 20, 21, 22, 25, 26 and 37; and it was ascertained by experiments that these springs arose from water which was passing under the floor from up-stream of the Barrage. (It may be noted here that, according to rumour, this portion of the Damietta Barrage is founded on tipped stone like the right flank of the Rosetta Barrage). A large inlet was discovered in front of bay 29-30. The inlet crater was filled with sacks of sand and an island of soil formed over it up to water-level, and the up-stream apron floor was also covered with soil. This weakened but did not stop the springs, as the soil was too light, but further work had to be postponed till the next season.

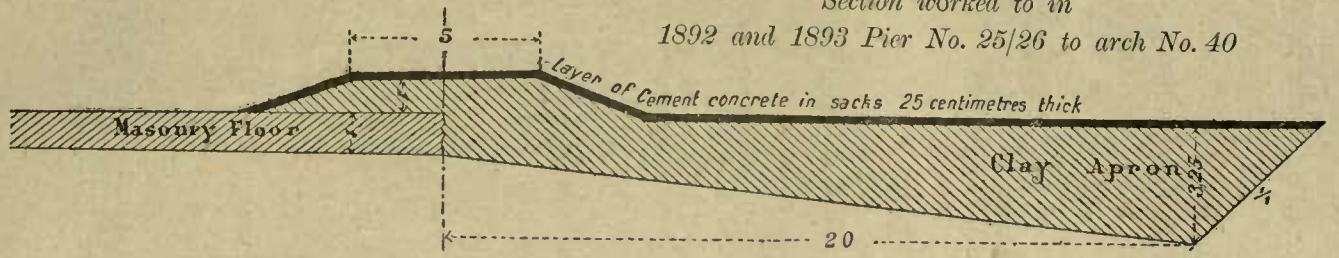
The following system for stopping the leaks was eventually adopted by Mr. E. W. P. Foster, late Inspector General of Irrigation in Lower Egypt. A trench of the dimensions given in the accompanying diagram (Fig. 13) was cleared of its rubble pitching and porous soil by dredging along the up-stream edge of the floor in front of from 3 to 5 bays a a time. This trench was then filled with stiff clay deposited in layers of half a metre thick, pressed down by means of a sledge drawn over it, to form an impervious curtain. Over the junction between the clay and the masonry floor a broad clay bank one metre high was formed and consolidated to make a tight joint: it was then covered with a layer of sacks filled with concrete and laid close together to protect the surface of the clay from erosion by the current. Great care had to be taken that this joint was properly cleared of loose material before the clay was laid on it, and that the concrete in sacks was carefully bedded and arranged. To do this a diving bell was made use of. Careful soundings made in 1895 over the whole area of concrete sacks showed that they had not been displaced by the flood.

Fig. 13

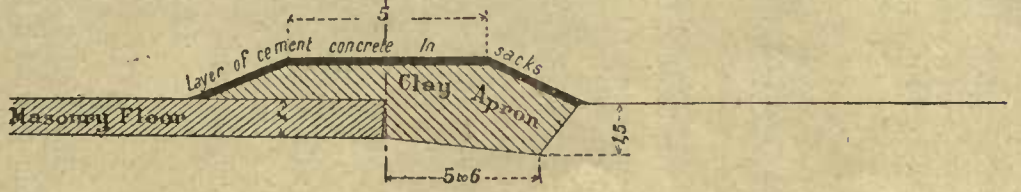
DAMIETTA BARRAGE UPSTREAM CLAY APRON

Scale $\frac{1}{200}$

Section worked to in
1892 and 1893 Pier No. 25/26 to arch No. 40



Section worked to in 1894
Pier No. 15/16 to Pier No. 25/26



Note: The work of 1882 (Pier 25|26 to arch 35) was not consolidated by the sledge, except only that part of it, which was taken up and relaid in 1893.

Dimensions in metres.

In 1892 and 1893 a bank had been made down-stream of the Barrage enclosing the springs, so as to decrease the head on them by letting the water rise in the enclosed pond, but this precaution was not considered necessary in 1894, as the springs had been almost entirely staunched.

In 1894 and 1895 three weak springs, throwing perfectly clear water, were detected below arches 21 and 26, but it was ascertained that these had no direct communication under the floor with the upstream side of the Barrage.

The springs, that were staunched by the formation of the clay apron, were in some way connected with the accident that happened during the fourth season's work of the Barrage restoration.

Benefits resulting from the successful completion of the restoration.

The benefits, that have followed as a consequence of the work done to the Barrage from 1887 to 1890, have been considerable and fully sufficient to justify all the expenditure incurred.

The increase in the cotton crop it is possible to show by figures, which, for the years succeeding 1880, have been obtained from the Alexandria General Produce Association and may be relied upon to be as accurate as possible. The figures for the years previous to 1881 were given in a list published some years ago by the Egyptian Gazette.

The first crop on the record is that of 1820, which produced 944 kantars: the next year the figure had increased to 35,108 kantars. (A kantar is about a hundred-weight.) From 1822 to 1848 the yield varied from 120,000 to 345,000 kantars.

In 1849 the yield was 364,816 kantars
1850 „ „ „ 384,439 „
1851 „ „ „ 670,129 „

The high figure of 1851 was not maintained, but the yield never fell again to what it had been before 1851. From 1852 to 1859 the year's

yield varied from 480,000 to 540,000 kantars. The few years following 1860 were a succession of record-beating years: —

In	1860	the	yield	was	590,200 kantars
	1861	„	„	„	721,052 „
	1862	„	„	„	1,181,888 „
	1863	„	„	„	1.718,791 „
	1864	„	„	„	2,001,169 „

The Barrage was declared to be finished in 1861, and it would seem from the foregoing figures to have had a great effect. But the increase in the cotton cultivation from 1861 to 1864 was due to the high prices obtained for Egyptian cotton during the American Civil War, which lasted from April 1861 to May 1865. It was this which gave such impulse to cotton growing in Egypt that the crop of 1864 produced almost four times that of any crop previous to 1860. But this increase was not kept up to its full extent after the war, as the figure fell from 1865 to 1869 to an average of about 1,300,000 kantars. It rose again, however, to between 2,000,000 and 3,186,000 kantars from 1870 to 1883.

Previous to 1884 the highest figure reached had been that of 1879, viz: 3,186,000. The figures for the years succeeding 1883 were as follow: —

Year	Kantars of Cotton	Nature of Summer supply
1884	3,630,000	Good
1885	2,900,000	Bad
1886	2,983,000	Mean (worms)
1887	2,965,000	Mean (worms)
1888	2,720,000	Bad (very late flood)
1889	3.240,000	Bad
1890	4,150,000	Bad
1891	4.765,000	Mean
1892	5,220,000	Bad
1893	5,033,000	Good
1894	4,615.000	Mean (worms)

Il will be noted that, since the Barrage was restored, the increase is

independent of the nature of the summer water supply: it is more dependent on the weather that prevails during the season when the bolls are mature, and upon the tender mercies of the cotton worm; for, until a storage reservoir has been made and more land reclaimed as a consequence, the area planted with cotton will not be capable of further extension, except on a small scale. But under favourable conditions of water supply and weather, combined with a scarcity of cotton worm during the flowering season, a yield of 5 ½ million or even 6 million kantars may not improbably be obtained, even without any further extension of the area planted.

Rice cultivation, which is also a summer crop, has increased at the same time with the increase of cotton, but reliable figures to show to what extent are not available.

The delivery of the water at a high level, in the canals dependent on the Barrage, has caused a large saving in cost of lifting and in coal expended for working steam pumps. Even the partial use of the Barrage in 1884 caused, according to the Railway returns, a falling off of 12,000 tons of coal supplied to the six principal towns of Lower Egypt during the first 7 months of the year, and this in spite of the fact that many steam pumps use cotton stalks as fuel instead of coal.

Another end gained by making the Barrage efficient was the avoidance of the necessity of adopting the alternative costly project of pumping stations, which, as has been already shown, would have yearly cost the country L. E. 248,500 to work, whereas the yearly expenditure in maintaining and working the Barrage is under L. E. 14,000.

Again, the raising of the water-level above the Barrage, combined with measures to maintain the Rayyah Beherah in an efficient state, which have also been a great success, resulted in the Province of Beherah being given a better supply by flow than the pumps at Khatatbeh and Atfeh, referred to before, could give. So these pumps were no longer required and the expense of pumping was therefore economised. From 1886 to 1889 this pumping had cost the Government annually from L.E. 80,000 to L.E. 90,000,

made up of a yearly subsidy of L.E. 26,320 and the remainder as payment at the rate of L.E. 42 per million cubic metres of water lifted.

As far as the fellaheen of Egypt are concerned, the greatest advantage gained by raising the water-level at the off-take of the main canals has been an enormous decrease in the quantity of silt clearance. This decrease has permitted of the abolition of the Corvée and made it possible to maintain the canals by paid labour working under contractors. The amount expended in Lower Egypt on the work formerly done by the Corvée is now under L.E. 200.000. For this expenditure the necessary maintenance works are fully executed, canals are remodelled and some new works carried out every year.

The number of unpaid labourers turned out to clear canals and repair banks in Lower Egypt (excluding Gizah) in 1883 was equivalent to 106,616 men, working for 100 days. In 1884 it was 88,299. Taking a man's labour per diem as worth 4 Piastres (1 franc), this labour was worth L.E. 426,466 in 1883 and L.E. 353,196 in 1884. And mereover with these numbers the work that was necessary was never completed, and remodelling and new works had become out of the question. For not only were the nominal numbers insufficient, but the actual numbers were still more so. In 1885 the Inspectors of Irrigation reported that the Corvée would not turn out: and naturally, for the koorbash had been abolished, and no inducement had been substituted for it. Thus, the koorbash being abolished, it became necessary to substitute paid for unpaid labour, and this was only made possible by the economy in the maintenance charges of canals effected by the restoration of the Barrage.

There is yet more to be said in its favour. The efficiency of the new closing gates, fixed in the Barrage, has made it possible to utilise the full discharge of the Nile during a bad summer, and to turn *all* the water into the canals for irrigation purposes. But, with this, certain disadvantages are connected: the Nile Branches below the Barrage are rendered unnavigable, and salt water travels up the branches from the Sea. To meet the first disadvantage, some of the principle canals have been made navigable by the construction of locks; and to meet the second objection, the canals in the

North of the Delta have been connected up with those fed from above the Barrage, so that irrigation and drinking water is provided by them to those villages and areas, which formerly obtained their supply in summer direct from the river.

The one great objection to the high-level water obtained by regulation on the Barrage is the danger of damaging lands by infiltration. This has actually taken place in some situations. The remedy appears to be a more complete system of drains and a more plentiful supply for washing the lands. Money is required both to dig the channels which will improve the drainage, and to make a storage reservoir which will give in summer the increased supply of water required for washing the salt out of the lands.

There is one other objection urged to the Barrage, but it is a fanciful one. It is accused of creating a stagnant pool above it, which is said to be injurious to the health of the dwellers in Cairo. This accusation has been made chiefly on the authority of one or two misinformed medical men, who adopt the *post hoc propter hoc* system of reasoning. Through what is loosely termed a "stagnant" pool the whole Nile flows past Cairo in a channel of no great dimensions. The minimum discharge of the Nile in summer may be taken to be 30 million cubic metres a day, or 347 cubic metres a second. To call a channel of 2700 square metres, through which such a discharge passes, a stagnant pool, is to employ a misnomer; and to consider that the reduction in the velocity of the flood, due to a holding up at the Barrage, is a cause of serious danger to the health of Cairo is to show a want of appreciation of th general sanitary condition of the capital of Egypt. If the inhabitants can live in the atmosphere and under the conditions that all but a favoured few do in Cairo, they are not likely to be affected by the fact that, instead of the river flowing past the town at the mean rate of 14 kilometres a day, it flows at the rate of 11 kilometres a day, the former rate being the mean velocity at lowest Nile with the Barrage open and the latter with it closed. The calculation of these velocities is made from a cross section of the river taken just South of Gezireh Palace.

It will be seen from the foregoing paragraphs that the results obtained

from the Barrage, where capable of being expressed in figures, are expressed in big ones. The original conception of such a work, to whomever it may belong, was a grand one. It was to the haste, with which the work was urged along, that the early failure must be charged.

It was further a bold thing, after the condemnation of the Barrage was almost unanimously pronounced, to attempt its restoration. The warnings of the cautious would have had it left alone to be a monument of confessed failure, and a witness, so long as it should stand, of the impotence of the present age within full view of the enduring Pyramids of a more robust past. But the Barrage fell into the hands of men, whose experience taught them to be bold without being rash, and who, having confidence in themselves, ventured what more timid men would not, in order that the country might win much by their successful daring, and the standing reproach of a useless Barrage be taken away from the builders of this century.

CHAPTER V.

Proposed operations for further security of Barrage foundations.

A perusal of the foregoing Chapters will probably leave the reader with the impression that, though the Barrage now performs its duty, it does so in spite of the fact that its present floor and foundations rest on a treacherous subsoil and that they are formed of patchwork, the subsequent additions to the original structure having been formed about an unsound nucleus, the radical defects of which necessitated those additions, so that the resulting work of to-day has little that is homogeneous about it. The three springs downstream of the Damietta Barrage floor, which are still yearly detected, as well as an old spring opposite arch N° 5 of the Rosetta Barrage, which was looked for and found in 1896, though not of a nature to cause anxiety, still show that there are some imperfections in the foundations or in the soil below the foundations on which the Barrages rest. Warnings have also been uttered from time to time, among them one by Sir C. Scott Moncrieff himself, pointing out that, though off the sick list, the Barrage is still of delicate constitution and must be handled with unceasing care and watchfulness.

A just appreciation of the immense importance of the Barrage to Lower Egypt, and a knowledge of the defective condition of the old foundations that lie under and within the later additions, create a feeling of uneasiness and apprehension in the minds of those who are responsible for the safe-keeping of

the work. Hence any proposals tending to remove the causes of this uneasiness are welcomed, though in the opinion of some it is better to leave well alone. On this principle of leaving well alone no work with the view of strengthening the foundations was undertaken in 1895 and 1896, but the springs were merely watched and the floors examined.

But in the spring of 1896 Mr. W. R. Kinipple M. I. C. E. came to Egypt to advise the Egyptian Government on the question of applying his system of "Stoek-ramming" to two locks on the Ismailiyah Canal, which had shown failure of foundations. Advantage was taken of his presence in Egypt to consult him as to the practability of applying his system to the Barrage, so as to make it sufficiently secure to remove all doubts as to its permanent stability. His report was encouraging.

After Mr. Kinipple had been asked to give his advice, some slight hair-cracks appeared in Arches N^{os} 7 and 8 of the Rosetta Barrage, but after their first appearance they did not enlarge. No doubt the appearance of these cracks removed any hesitation that might have been felt as to the desirability of adopting Mr. Kinipple's system as a means of making the foundations of the Barrage secure.

It has, therefore, been decided to commence work after the flood of 1896 on 11 arches of both Barrages opposite the springs which are known to exist. If the springs are thereby stopped and the operations are otherwise satisfactory and successful, the rest of the two Barrages will be similarly treated in subsequent years. The Government has been fortunate enough to secure the services of Mr. Kinipple himself for superintending the first season's experimental work.

The system consists in forcing plastic clay under pressure down holes bored through the masonry and floor, the pressure causing the clay to spread itself out under the floor and foundations and to displace the shifting sand it meets with, or render it so compact as to make it capable of resisting without leaks the maximum water pressure desired.

In the case of the Barrage, three vertical holes, situated 3 $^1/_2$ metres apart on the longitudinal axis of each pier, will be bored down to the underside

of the lowest layer of the foundations. These holes will then be lined with iron tubes, and the clay, formed into pellets, will be passed down them and be subjected to pressure.

It is hoped that the clay from adjacent piers will meet under the flooring between the piers and there unite, to as to form a continuous water-tight curtain wall under the centre of the Barrage. But at present such work belongs to the future history of the Barrage and any further account of it may therefore be left to the future.

CAIRO, 24 July 1896.

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ERRATA.

Page 5 line 6 for "ancients" read "anicuts"
„ 5 „ 14 for "Jurther" read "Further"
„ 13 „ 1 for "to the floor" read "of the floor"
„ 17 „ 25 for "fill" read "fit"
„ 33 „ 23 for "refers them" read "refers to them"
„ 47 „ 22 for "verbalim" read "verbatim"
„ 59 „ 11 for "wich" read "which"